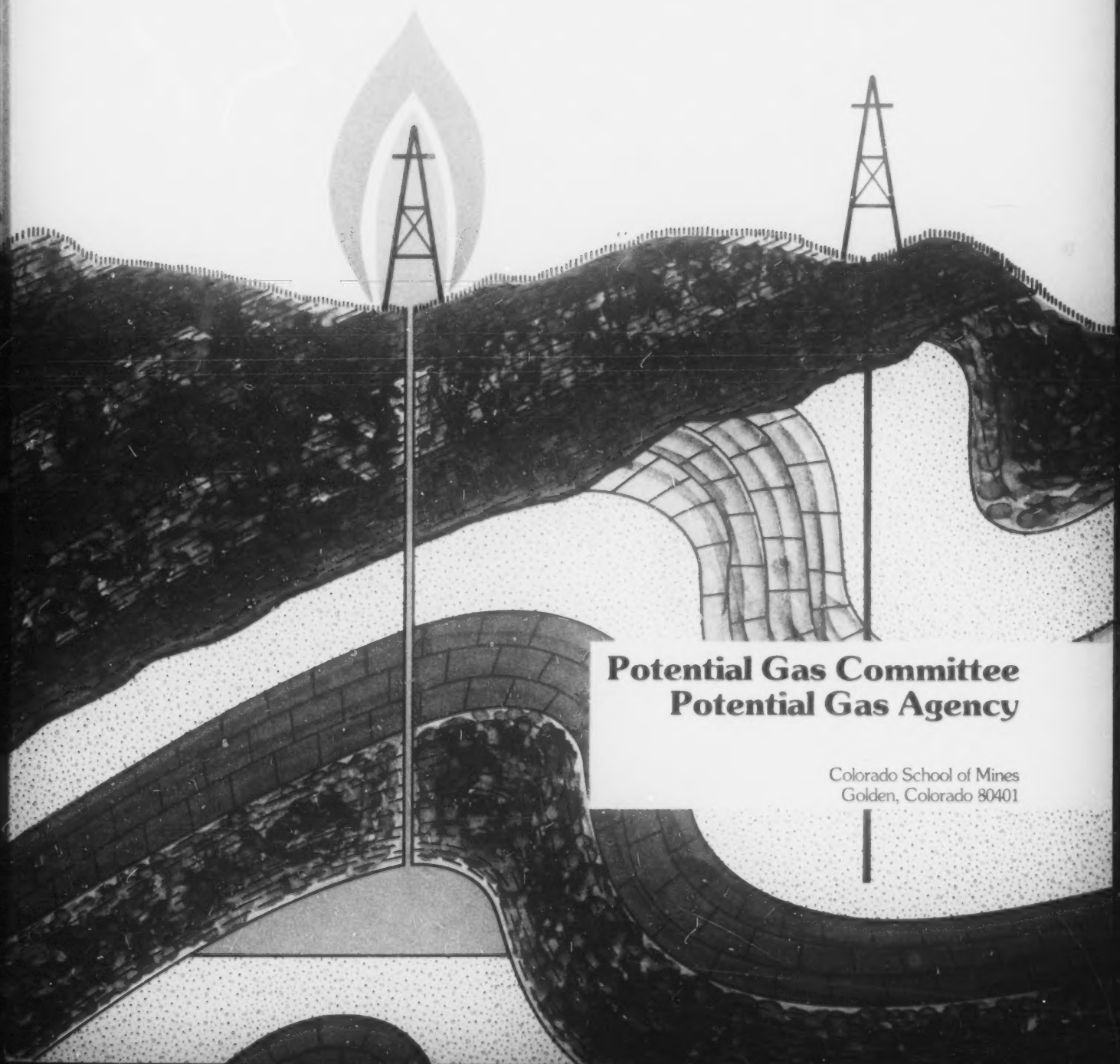


R8765-14 4/89

POTENTIAL SUPPLY OF NATURAL GAS IN THE UNITED STATES

(December 31, 1988)



**Potential Gas Committee
Potential Gas Agency**

Colorado School of Mines
Golden, Colorado 80401

The Potential Gas Committee comprises volunteer members from the natural gas industry, government agencies, and academic institutions who are concerned with natural gas resources.

The Committee functions independently but with the guidance and assistance of the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association.

Published by

Potential Gas Agency
Colorado School of Mines
Golden, Colorado 80401
303-279-4320

Staff of the Potential Gas Agency

Harry C. Kent, Director
Joseph J. Finney, Associate Director
Sharon J. Kirts, Staff Assistant

Per Copy Price: US \$30.00 United States
(Prepaid) US \$40.00 Foreign mailing
Postage charges will be added if payment does not accompany order.
Express charges extra.

POTENTIAL SUPPLY OF NATURAL GAS IN THE UNITED STATES

(December 31, 1988)

Report of the Potential Gas Committee

Richard J. Burgess, President/General Chairman

Editorial Committee

William E. Mantek, Chairman

A. M. Derrick

J. Scott Jenkins

Mike Knobloch

David A. Rochester

ex officio:

Richard J. Burgess

Harry C. Kent

**Potential Gas Agency
Colorado School of Mines**

April 1989

“Where gas is first found, in the final analysis, is in the minds of men.”

adapted from
Wallace Pratt
American Association of
Petroleum Geologists
Bulletin
December, 1952

“We usually find gas in new places with old ideas. Sometimes, also, we find gas in an old place with a new idea, but we seldom find much gas in an old place with an old idea. Several times in the past we have thought that we were running out of gas, whereas actually we were only running out of ideas.”

adapted from
Parke A. Dickey

PREFACE

The objective of the Potential Gas Committee is to provide estimates, based upon expert knowledge, of the potential supply of natural gas which, in conjunction with estimates of proved reserves of natural gas, make possible an appraisal of long-range gas supply.

For many years, estimates of future supply of natural gas have been developed by numerous individuals and organizations. Since these estimates of future supply have varied widely and often have had entirely different objectives and meanings, they have served to confuse rather than to clarify the long-range outlook for natural gas supply. With the view to achieving a more unified industry-sponsored effort, many leaders of the natural gas industry, as well as various financial and governmental agencies, sought a longer-range, ongoing, study of the requirements and supply of natural gas in the United States. As a result of this concern, the work of the Potential Gas Committee was initiated in 1960. The Committee, in early years known as the Future Gas Supply Committee, has functioned since that time and has prepared regular reports presenting estimates of the recoverable natural gas which is believed to exist in addition to proved reserves. Since 1967 the work of the Committee has been guided and assisted by the Potential Gas Agency of the Colorado School of Mines.

Discussions of the geology and the natural gas potential are presented for each of the geographic areas included in 89 geologic provinces of the lower 48 states and Alaska. Fifty-five of these geologic provinces are in onshore areas and 34 are offshore. For each of the onshore provinces, separate estimates are given for (1) resources estimated to occur at drilling depths of less than 15,000 feet and (2) those estimated to occur at drilling depths between 15,000 and 30,000 feet. Offshore provinces are separated into those that occur beneath water depths of less than 200 meters (continental shelf) and those that occur beneath water depths of 200 to 1,000 meters (upper continental slope). A new province (P-945, Gulf of Mexico Outer Continental Slope), which encompasses the territorial waters of the United States deeper than 1,000 meters in the Gulf of Mexico, has been included for the first time in this report.

Resource estimates for each geologic province are given in terms of maximum, most likely, and minimum estimates. The Potential Gas Committee believes that this manner of reporting gives users an understanding of the uncertainty involved in the resource estimate for any one province. Resource estimates in this report are expressed in terms of billion cubic feet (Bcf) of estimated natural gas resource potential.



CONTENTS

REPORT OF THE POTENTIAL GAS COMMITTEE	1
SUMMARY	1
INTRODUCTION	4
DEFINITION OF NATURAL GAS	5
CATEGORIES OF NATURAL GAS RESOURCES	5
ESTIMATION OF POTENTIAL GAS SUPPLY	11
Geological Provinces and work areas	11
Estimation Procedures	11
LIMITING CONSIDERATIONS	13
Drilling Depth and Water Depth Limitations	13
Economic, Technological and Policy Considerations	14
NATIONAL SUMMARY STATISTICS	15
 POTENTIAL GAS COMMITTEE	
NATURAL GAS RESOURCE ESTIMATES	23
ATLANTIC AREA	25
P-100, New England Province and Adirondack Uplift	25
P-110, Atlantic Coastal Basin	25
P-120, Appalachian Basin	25
P-130, Piedmont-Blue Ridge Province	28
P-140, South Georgia-Peninsular Florida Sedimentary Province	30
P-150, Black Warrior Basin	30
P-910 and P-911, Atlantic Offshore, Shelf and Slope	32
P-915 and P-916, West Florida Offshore, Shelf and Slope	33
NORTH CENTRAL AREA	37
P-200, Michigan Basin	37
P-210, Cincinnati Arch	38
P-220, Illinois Basin	39
P-230, Upper Mississippi Embayment	41
P-240, Wisconsin Arch, Sioux Uplift and Iowa Shelf	41
P-250, Lincoln Anticline and Ozark Uplift	41
P-260, Forest City Basin and Cherokee Basin	43
GULF COAST AREA	47
P-300, Louisiana-Mississippi-Alabama Salt Basins	47
P-310, Louisiana Gulf Coast Basin (Onshore)	49
P-320, East Texas Basin	50
P-330, Texas Gulf Coast Basin (Onshore)	52
P-930 and P-931, Eastern Gulf Coast Offshore, Shelf and Slope	52
P-935 and P-936, Louisiana Offshore, Shelf and Slope	53
P-940 and P-941, Texas Offshore, Shelf and Slope	53
P-945, Gulf of Mexico Outer Continental Slope	54

MID-CONTINENT AREA	57
P-400, Central Kansas Uplift, Salina Basin, Nemaha Anticline and Sedgwick Basin	57
P-410, Arkoma Basin	59
P-420, Anadarko Basin, Palo Duro Basin, Amarillo Arch and Chataqua Platform	59
P-430, Fort Worth Basin, Bend Arch and Strawn Basin	61
P-440, Permian Basin	63
ROCKY MOUNTAIN AREA	69
P-500, Williston Basin	70
P-510, Powder River Basin	71
P-515, Big Horn Basin	73
P-520, Wind River Basin	75
P-530, Greater Green River Basin, Hanna and Laramie Basins	76
P-535, Denver Basin, Chadron Arch and Las Animas Arch	77
P-540, Uinta-Piceance Basin, Park Basins and Eagle Basin	82
P-545, San Juan Mountains, San Luis Basin, Las Vegas-Raton Basin, Sierra Grande Uplift	83
P-550, Paradox Basin	85
P-555, San Juan Basin	87
P-560, Southern Basin and Range Province	89
P-565, Plateau Province and Black Mesa Basin	90
P-570, Sweetgrass Arch and Central Montana	93
P-575, Montana Folded Belt	93
P-580, Snake River Basin	95
P-590, Wyoming-Utah-Idaho Thrust Belt	96
PACIFIC AREA	101
P-600, Oregon-Washington Coastal Basins, Okanogan Province	102
P-610, Eastern Columbia Basin	102
P-620, Great Basin, Sierra Nevada, Klamath Mountains and Southern Oregon	102
P-630, Southeastern California Basins	104
P-640, Sacramento Basin	104
P-650, San Joaquin Basin	105
P-660, California Coastal Basins	107
P-960 and P-961, Pacific Offshore, Shelf and Slope	109
ALASKA AREA	113
P-701, Alaska North Slope	113
P-702, Alaska Southern Foothills and Brooks Range	114
P-703, Yukon Flats Basin and Kandik Basin	114
P-704, Alaska Interior Basins	115
P-705, Northern Gulf of Alaska (Onshore)	115
P-706, Southeastern Alaska	115
P-707, Cook Inlet-Susitna Province (Onshore)	116
P-708, Alaska Peninsula-Shelikof Province (Onshore)	116
P-709, Alaska Peninsula-Bristol Bay (Onshore)	116
P-710, Aleutian Islands	117
P-971 and P-972, Beaufort Sea, Shelf and Slope	117
P-973, Chukchi Shelf	117
P-974, Norton Basin	117
P-975, Hope Basin	118

P-979, St. Matthew Basin-Bethel Basin Shelf	118
P-980, Southwest Bering Sea Slope	118
P-981 and P-982, Navarin Basin, Shelf and Slope	118
P-983 and P-984, St. George Basin, Shelf and Slope	118
P-985, Bristol Bay Basin Shelf	119
P-987 and P-988, Shumagin-Kodiak Shelf and Slope	119
P-989 and P-990, Aleutian Shelf and Slope	119
P-991, P-992, P-993 and P-994, Northern Gulf of Alaska and Southeastern Alaska, Shelf and Slope	119
P-995, Cook Inlet Basin, Offshore	119
NATURAL GAS RESOURCES FROM COAL SEAMS	123
Introduction	123
Definition of Coalbed Methane	123
Resources of Coalbed Methane	124
Production of Coalbed Methane	127
Black Warrior basin, Alabama	128
San Juan basin, Colorado and New Mexico	130
POLICY GUIDELINES	133
GENERAL POLICY STATEMENT	133
GAS SUPPLY COMMITTEE OF THE AMERICAN GAS ASSOCIATION ..	133
POTENTIAL GAS AGENCY OF THE COLORADO SCHOOL OF MINES ..	134
POTENTIAL GAS COMMITTEE	136
AREA WORK COMMITTEES	138
STANDING COMMITTEES OF THE POTENTIAL GAS COMMITTEE	140
Board of Directors	140
Editorial Committee	140
Committee on Definitions and Procedures	140
Time and Site Committee	141
COMMUNICATIONS	141
Communication Between Committees	141
Public Communication	141
MEMBERSHIP OF THE POTENTIAL GAS AGENCY AND POTENTIAL GAS COMMITTEE	142

PLATE

<i>Plate</i>	<i>Title</i>
1	Potential Gas Committee Natural Gas Map of the United States 12/31/88 In pocket

ILLUSTRATIONS

<i>Figure</i>	<i>Title</i>
1	Schematic Representation of Progression of Categories of Potential Natural Gas Resources as a Result of Drilling and Reappraisal 3
2	Natural Gas Resource Categories 7
3	Schematic Representation of Categories of Potential Resources 9
4	Potential Gas Committee Work Areas and Geologic Provinces 12
5	Cumulative Production, Proved Reserves and Potential Resources of Natural Gas in the Total United States 19
6	Cumulative Production, Proved Reserves and Potential Resources of Natural Gas in the Lower 48 States 19
7	Estimates of Ultimately Recoverable Resource of Natural Gas in the Total United States 20
8	Estimates of Ultimately Recoverable Resource of Natural Gas in the Lower 48 States 20
9	Coalbed Methane Resources of the U.S. 125
10	Producing Wells in the Warrior Basin 129
11	Annual Production in the Warrior Basin 129
12	Coalbed Methane Wells, San Juan Basin, Colorado and New Mexico 131
13	Annual Production of Coalbed Methane, (Ignacio Blanco, Cedar Hill and Meridian fields), San Juan basin, Colorado and New Mexico 131
14	Annual Production from Cedar Hill Field, San Juan Basin 132
15	Organization of Potential Gas Resource Studies 135
16	Organization of Potential Gas Committee 136

TABLES

<i>Table</i>	<i>Title</i>
1	Estimated Potential Natural Gas Resources 1
2	Potential Gas Committee 1988 Estimates by Area 16
3	Potential Gas Committee 1988 Estimates—Total United States 17
4	Comparison of Estimates of Ultimately Recoverable Volumes of Natural Gas in the United States 18
5	Comparison of Estimates of Potential Resources of Natural Gas from Potential Gas Committee Reports 21
6	Comparison of Estimates, 1986 and 1988, by Area 22
7	Estimated Resources of Natural Gas for Provinces of the Atlantic Area 35
8	Estimated Resources of Natural Gas for Provinces of the North Central Area 45
9	Estimated Resources of Natural Gas for Provinces of the Gulf Coast Area 55
10	Estimated Resources of Natural Gas for Provinces of the Mid-Continent Area 66
11	Estimated Resources of Natural Gas for Provinces of the Rocky Mountain Area 98
12	Estimated Resources of Natural Gas for Provinces of the Pacific Area 110
13	Estimated Resources of Natural Gas for Provinces of the Alaska Area 121
14	Estimated Coalbed Methane Resources, Selected Basins in Conterminous United States 126

REPORT OF THE POTENTIAL GAS COMMITTEE

Summary

The Potential Gas Committee comprises volunteer members from all segments of the oil and gas industry, government agencies and academic institutions who are concerned with natural gas resources. This Committee has prepared and published biennial estimates of the potential supply of natural gas since 1964, with the exception of 1974. Members of the Committee, their experience and affiliations, are listed in the last section of this report. The Committee functions independently

but with the guidance and assistance of the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association.

The Potential Gas Committee's most likely estimate of the potential supply of natural gas in the United States, as of December 31, 1988, is shown on Table 1:

Table 1. Estimated potential natural gas resources
(billion cubic feet)

	Most likely estimates			
	Probable	Possible	Speculative	Total
Traditional Resources				
Lower 48 States				
--Onshore	137,850	173,800	116,100	427,750
--Offshore	26,600	64,150	68,450	159,200
Total Lower 48 States	164,450	237,950	184,550	586,950
Alaska				
--Onshore	6,350	16,400	27,700	50,450
--Offshore	2,400	12,700	53,000	68,100
Total Alaska	8,750	29,100	80,700	118,550
Total United States	173,200	267,050	265,250	705,500
Coalbed Methane				90,100
Grand total United States				795,600

These estimates represent the conventional potential natural gas resources expected to be recovered by future drilling under conditions of:

1. adequate economic incentives in terms of price/cost relationships, and
2. current or foreseeable technology.

Estimates of the PGC are "base-line" estimates since they attempt to provide a reasonable appraisal of the total natural gas resource potential of the United States and are not limited by assumptions of the time of development of the natural gas resource, the life span of the natural gas industry, or the specific price to be paid for the produced gas. There is no consideration of whether or not this resource will be developed; rather, the estimates are of the resource that could be developed if the need and economic incentive exist. Estimates also assume no governmental or regulatory restraints upon the development and production of the resource.

The Potential Gas Committee's estimates do not include, and are distinct and separate from, the volume of proved recoverable natural gas reserves contained in the nation's discovered fields. The relationship between proved reserves and the several categories of potential natural gas resources is illustrated in Figures 1, 2 and 3, and described in detail in the section on Categories of Natural Gas Resources.

The Potential Gas Committee's previously published *most likely* estimates, as of December 31, 1986, were as follows (in billion cubic feet): Probable 162,635, Possible 298,294, and Speculative 277,627. More detail is included in Tables 2 to 6 and in the reports of the various areas. Comparison of the totals of the *most likely* estimates of potential resources for year end 1986 with the new estimates presented in Table 1 reveals a decrease in the estimates for traditional gas resources from 738,556 Bcf (1986) to 705,500 Bcf (1988). These estimates represent, however, the current status of a dynamic system in which former potential resources pass into proved reserves and ultimately production through discovery and development of new pools and fields (Figure 1). Concurrently the estimates of remaining potential resources are revised based on knowledge gained through additional exploration and drilling. In addition to estimates of traditional resources, the year-end 1988 Potential Gas Committee estimates include an estimate of recover-

able coalbed methane of 90,100 Bcf. When added to the estimates of traditional resources this brings the total estimate of recoverable resources to 795,600 Bcf, an increase of 57,044 Bcf from 1986 to 1988.

A considerable portion of the change in resource estimates between succeeding biennial reports of the Potential Gas Committee is represented by the additions to Proved Reserves which have taken place in the preceding two years. Such reserve additions are estimated to the best of their ability by PGC members based upon available data, and the additions are then removed from the appropriate resource categories. Decreases in estimates of Probable resources occur because of field development and additions to reserves as a result of extensions of the producing area of the pool or field. Additions to estimates of Probable resources are made based upon the undeveloped areas of fields which have been discovered and are under development at the time the resource estimates are prepared. Estimates of Possible resources are decreased based upon new field discoveries and increased when new provinces or formations are demonstrated to be productive of natural gas. Estimates of Speculative resources are reduced based upon new field discoveries and may be increased if new data indicate additional, previously unrecognized, potential for natural gas discoveries and production.

Major changes in resource estimates, especially estimates of Speculative resources, most frequently occur in frontier areas, such as some offshore regions, deeper portions of some onshore basins, Alaska, and portions of the Rocky Mountain states. These changes reflect the uncertainty of resource estimation where available geological and geophysical data are limited and where new exploration may bring about significant changes in the knowledge and interpretation of the nature and occurrence of the natural gas resource.

In addition to expected changes resulting from potential resources passing into Proved Reserves, the following significant changes in resource estimates have been made:

In the Gulf Coast Area, a major new province (P-945, Gulf of Mexico Outer Continental Slope) was added to the previous areas assessed for resource potential. This province encompasses virtually all of the territorial waters of the United States in the Gulf of Mexico beneath water depths greater than 1,000 me-

ters. There has been significant leasing activity in this region in recent years with some portions of the province receiving active bidding for leases from a number of companies, especially major producing companies. PGC members believe that this province has significant potential for future discoveries of natural gas; the *most likely* estimate for Speculative potential in the province is 30,000 Bcf. The four onshore geologic provinces of the Gulf Coast Area [P-300, Louisiana-Mississippi-Alabama salt basins; P-310, Louisiana Gulf Coast basin (onshore); P-320, East Texas basin; and P-330, Texas Gulf Coast basin (onshore)] were the subject of extensive reevaluation by the Gulf Coast Committee. Based on this work, resource estimates were increased significantly for all resource categories in the Texas Gulf Coast basin and for the Probable and Possible resource categories in the East Texas basin. At the same time, however, there is a marked decrease in the resource estimates in the Possible category for the Louisiana-Mississippi-Alabama salt basins.

Reevaluation of the resource potential for the Mid-Continent Area has resulted in a downward revision in one province and the inclusion of a deep resource

potential for the first time on another province. Based on disappointing results of exploration and poor production performance of some wells completed in the deep portion of the basin, the estimate of potential resources for the province (P-420) which includes the Anadarko basin has been revised downward from 139.2 to 78.3 Tcf for the depths below 15,000 feet. New discoveries of deep Arbuckle Formation gas in the Arkoma Basin (Province P-410) has resulted in the new allocation of potential resources to the deep portion of the basin.

In the Rocky Mountain Area, the estimates for the deep portion of the Wind River basin in both the Probable and Possible categories each have been increased about 1 Tcf because of improved reservoir characteristics encountered in a second deep test at Madden field. The estimate of Possible resources at depths less than 15,000 feet for the Greater Green River basin were increased 4.2 Tcf because of better reservoirs anticipated in the Cretaceous section in the western part of the basin. At the same time the Possible estimates for the depths from 15,000 to 30,000 feet were reduced 7.9 Tcf because of poorer reservoir char-

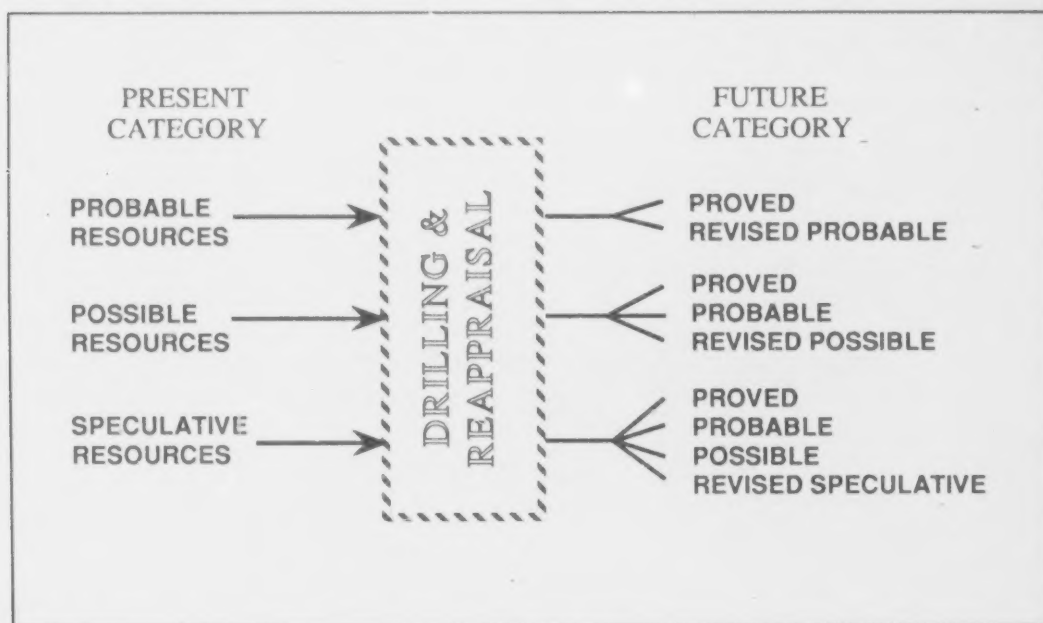


Figure 1. Schematic representation of progression of categories of potential natural gas resources as a result of drilling and reappraisal.

acteristics than initially anticipated in the Mesozoic section. Probable and Possible estimates for the Uinta and Piceance basins at depths less than 15,000 feet were both increased nearly 2 Tcf in order to account for bypassed reservoir sections currently behind pipe and future infill drilling. In the San Juan basin, the Possible estimate for depths less than 15,000 feet has been decreased 2.5 Tcf because recently drilled dry holes have condemned large portions of the area formerly considered potential for Possible resources. The Speculative potential for the Wyoming-Utah-Idaho Thrust Belt has been reduced approximately 3 Tcf because review of available data indicates poorer than anticipated reservoir characteristics in subthrust Cretaceous rocks.

There have been no significant changes in resource estimates for the Atlantic, Pacific, and Alaska areas.

The increasing importance of coalbed methane makes more detailed analysis of this resource vital, since it is the subject of extensive current development. The current status of coalbed methane production is summarized in a separate chapter. Production in the two principal producing basins, the Black Warrior basin of Alabama and the San Juan basin of New Mexico and Colorado, has increased significantly in the past two years. The PGC is moving in the direction of preparing estimates of recoverable coalbed methane resource as it does for the more traditional resources, but as yet it does not have sufficient data to make estimates that are of the same quality and detail as those for the traditional gas resources. However, some basins have now been assessed for recoverable resources and the estimated recoverable gas from these assessed basins is approximately 90.1 Tcf with existing or foreseeable technology.

Introduction

The estimates of the Potential Gas Committee are of natural gas which, in the judgment of Committee members, can be recovered by conventional means given adequate economic incentives in terms of price/cost relationships and utilizing current or foreseeable technology. Since these potential resources have not yet been confirmed by drilling and testing, there can be no rigorous evaluation of the economic viability of the resources. The accumulations, however, are believed to exist in concentrations which are of sufficient size and quality, considering geographic distribution and depth of occurrence, to warrant exploration and development.

The Potential Gas Committee's estimates do not include proved reserves. Annual estimates of proved reserves of natural gas in the United States were prepared, from 1946 through 1979, by the Committee on Natural Gas Reserves of the American Gas Association. Currently that Committee publishes an annual report containing estimates of proved reserves for selected fields.¹ Since 1977, and continuing to the present, annual estimates of proved reserves have been prepared independently by the Energy Information Administration of the U.S. Department of Energy.² These estimates are, by definition, limited to those estimated proved recoverable reserves of natural gas which have been established by drilling. Such estimates do not reflect potential resources of natural gas which may be discovered as a result of future exploratory drilling. It is the estimates of potential resources which are the concern of the Potential Gas Committee and which are discussed in this report.

¹American Gas Association, 1988, Natural Gas Reserves of selected Fields in the United States and of Canada prepared by the American Gas Association and the Canadian Petroleum Association as of December 31, 1987.

²Energy Information Administration, 1988, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1987 Annual Report: U.S. Department of Energy, Energy Information Administration, Washington, D.C., 105 p. [DOE/EIA-0216(87) and reports for earlier years].

Additionally, the Potential Gas Committee estimates do not include natural gas which may be recovered in the future from sources which are not currently recoverable with existing technology and under current or foreseeable economic conditions. Examples of such sources which are not included are gas from hydrates, gas from geopressed-geothermal accumulations, deep-earth gas or gas contained in very low permeability formations not recoverable with existing or foreseeable technology. As technology and economic conditions change, the Potential Gas Committee reviews its estimates and revises them as appropriate.

Definition of Natural Gas

Natural gas, as used in this report, is any gas (at standard conditions of temperature and pressure, 14.73 psia and 60° F) of natural origin that is composed primarily of hydrocarbon molecules producible from a borehole. Most natural gas contains some nonhydrocarbon components, such as carbon dioxide, nitrogen, hydrogen sulfide and helium. In estimating potential supply, it is not feasible to separate small volumes of these components from the hydrocarbons; however, in areas where significant volumes of such nonhydrocarbons are believed to occur, only the hydrocarbon components are included in the estimated potential supply.

Categories of Natural Gas Resources

A finite volume of natural gas-in-place exists within the rocks of the shallow portion of the earth's crust. This finite volume of gas-in-place is the total natural gas resource. The amount of this resource that is recoverable is a function of technology and economics. The categories of this resource are shown in Figure 2. Today, technology has advanced to the degree that a significant part of the natural gas resource base can be recovered. A major part of this resource, however, is dispersed throughout the earth's crust in such minute accumulations or under such conditions that it cannot

be extracted with existing or foreseeable technology. Also, the cost of recovery of such gas would be too high compared to the value of the gas. Even with likely advances in technology, production of some deposits would not be feasible because recovery of such accumulations would require more energy than that provided by the gas produced. The recoverable resource is that part of the resource that is susceptible to discovery and production during the life of the industry using current or foreseeable technology and under the condition that the price/cost ratio would be favorable.

The above limitations of size of accumulation and economics are applied as follows. For situations in which a distribution of sizes of individual accumulations is envisioned (particularly in estimation of probable and possible resources, as described below), a minimum size of recoverable accumulation is determined on the basis of the estimator's current judgment of the relationship between the value of the resource and the cost of drilling and production. This relationship is based on extrapolation of the prevailing price/cost ratio at that time for the given geologic province and depth. This often takes the form of an estimate of the minimum recovery per well, which is necessary in order for an operator to determine that it is economically feasible to complete and produce the well in a given geographic area and depth. Such a well may not, in total, be an economically viable venture, but given that the well has already been drilled to the target, the available resource will be produced and will probably recover the costs of completion and production, even if the total costs of exploration and drilling are not recovered. At the other end of the size and economic spectrum, a maximum size of accumulation is estimated on the basis of the estimator's evaluation of the geologic factors controlling the size and effectiveness of traps and the reservoir conditions.

The size and economic limitations are evaluated in a much more general way in situations in which it is not possible to estimate the number and sizes of individual accumulations. This is particularly the case in the estimation of speculative resources (as discussed below). In these situations, analogies are made with provinces or formations in which natural gas production has already been established and which have similar geologic characteristics to the unexplored province or formation. It is hoped that, if these analogies are drawn carefully and accurately, the analogous conditions of size and economics will also apply.

The Recoverable Resource is composed of both discovered and undiscovered natural gas resources. Discovered gas consists of the quantity produced in past years plus that proved by drilling and engineering tests and included in present Proved Reserves. Discovered gas also includes the gas remaining in known fields that will be recovered through extension and complete development of known pools and reservoirs. The undiscovered resource consists of the potential gas supply that could become productive with further exploration and development. The undiscovered resource includes both the gas remaining in undiscovered pools and reservoirs within known fields and the gas that may be discovered in new fields and reservoirs within geologic provinces that are presently productive and those that are as yet unproductive.

The subdivision of the recoverable resource into categories reflects the variation in the amount of geologic and engineering information on which the estimate is based. These categories are independent of any interpretation of the cost of development and production of the gas. Proceeding from left to right in Figure 2, the level of geologic and engineering knowledge decreases.

Cumulative production is the total volume of natural gas which has been withdrawn from producing reservoirs. Some uncertainty involving the amount of production from earlier years exists as a result of incomplete records, but a reasonable estimate has been made based on available information. Estimates of past production presented in this report have been prepared by the Committee on Natural Gas Reserves of the American Gas Association (CONGR). Annual production for years up to 1979 was obtained from the reports of CONGR.³ Annual production for years from 1980 to the present was obtained from the reports of the Energy Information Administration (EIA) of the U. S. Department of Energy.⁴

³American Petroleum Institute, American Gas Association, Canadian Petroleum Association, 1979, Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1979: American Petroleum Institute and American Gas Association, Washington, D.C., 253 p. (also annual reports for preceding years).

⁴op. cit.

Proved Reserves are the currently estimated quantities of natural gas which analysis of geologic and engineering data demonstrate with reasonable certainty to be recoverable in the future from known oil and gas reservoirs under existing economic and operating conditions. Reservoirs are considered proved that have demonstrated the ability to produce by either actual production or conclusive formation tests. The existence and quantity of gas have been *confirmed* by testing. The PGC does not estimate volumes of proved reserves. Estimates of proved reserves were compiled annually from 1946 through 1979 by the Committee on Natural Gas Reserves of A.G.A. (CONGR).⁵ The A.G.A. estimates have been largely supplanted by reports prepared by EIA which began with data for 1977 and have replaced the A.G.A. estimates for 1980 and subsequent years.⁶

There are differences in definition of proved reserves used by various reporting organizations as well as by individual companies. Recently adopted definitions by the Society of Petroleum Engineers⁷ restrict proved reserves to reserves which are supported by actual production or formation tests and by extrapolation of such tests to both drilled and undrilled locations. Proved reserves are further restricted to those commercially recoverable and marketable under existing economic conditions at the time of the estimate. There must also be operational facilities to process and transport the reserves to market or a commitment exist to install such facilities. Under these new definitions, and with the economic conditions prevailing in the natural gas industry in recent years, companies have removed some reserves from the category of proved reserves. This has been particularly apparent in Alaska where considerable quantities of reserves on the North Slope have been so removed. Other reporting organizations, notably EIA and CONGR, have exercised more latitude in the application of economic yardsticks and the installation of processing and transport facilities and

⁵op. cit.

⁶op. cit.

⁷Approved by the Board of Directors, Society of Petroleum Engineers (SPE), Inc., February 27, 1987.

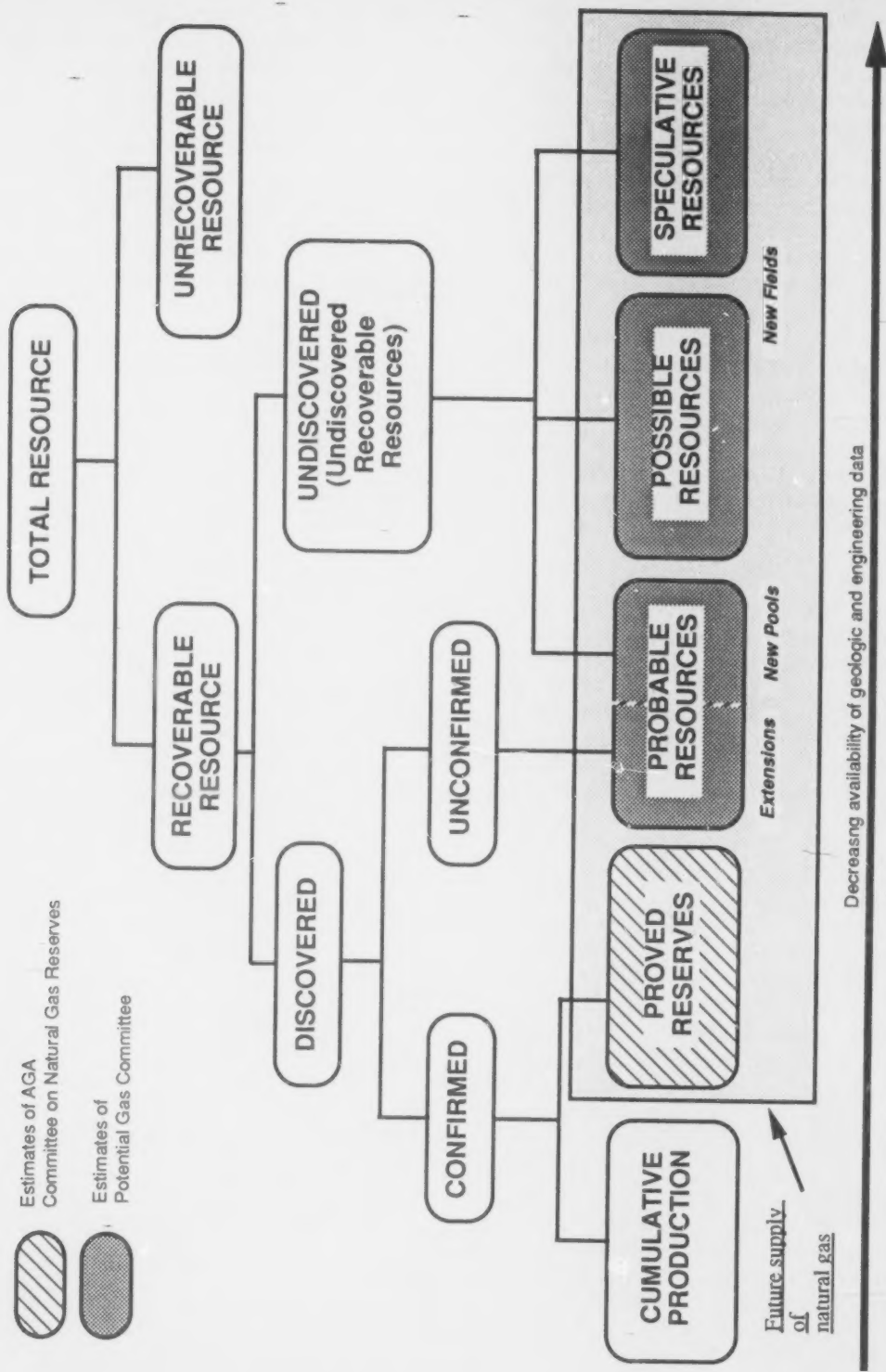


Figure 2. Natural gas resource categories

have retained estimates for proved reserves on the North Slope of Alaska. This has left the status of some proved reserves uncertain. Since the Potential Gas Committee attempts to make certain that its estimates coordinate with those of EIA and CONGR, it has not included in its estimates those proved reserves included in EIA and CONGR reports. A note has been added to the resource estimates for Alaska to draw attention to this matter.

Potential resources. The estimates of the PGC include all of the undiscovered resource plus the portion of the discovered gas resource that is not included in proved reserves (shaded area in Figure 2.) Three categories of potential resources are recognized and reported by the PGC: Probable, Possible and Speculative. These three categories are differentiated on the basis of variation in available geologic, geophysical and engineering information. Estimates of both non-associated and associated or dissolved gas are included in all categories.

Limitations to the estimates have been established by the PGC on the basis of current technological capabilities and an estimate of the expansion of those capabilities in the foreseeable future. No estimate is made for onshore areas of natural gas that might exist at drilling depths in excess of 30,000 feet. Estimates for onshore areas are also made for two depth intervals, 0-15,000 feet and 15,000-30,000 feet, in recognition of the greater costs and technical requirements for wells drilled below 15,000 feet. No estimate is made for offshore areas of any natural gas that might exist beneath water depths greater than 1,000 meters except for the Gulf of Mexico. Also, separate estimates are made for offshore areas of resources below water depths of 0-200 meters and depths of 200-1,000 meters, respectively, because of the higher costs associated with drilling platforms, production facilities and pipelines in deeper water. For the Gulf of Mexico an additional province incorporating U.S. territorial waters deeper than 1,000 meters has been included with this report for the first time.

Probable resources are associated with known fields and are the most assured of potential supplies. A relatively large amount of geologic and engineering information is available to aid in the estimation of the resource existing in this category. Probable resources bridge the boundary between discovered and undiscovered resources. The discovered portion includes the

supply from future extensions of *existing pools* in known productive reservoirs [1]*. The pools containing this gas have been discovered, but the extent of the pool has not been completely delineated by development drilling. Therefore, the existence and quantity of gas in the undrilled portion of the pool are as yet *unconfirmed*. The undiscovered portion is expected to come from future *new pool* discoveries within existing fields either in reservoirs productive in the field [2], or in shallower or deeper formations known to be productive elsewhere in the same geologic province or subprovince [3].

Possible potential resources are a less assured supply because they are postulated to exist outside of

*Numbers in brackets refer to accumulations shown diagrammatically in Figure 3.

Explanation for Figure 3—Schematic representation of categories of potential resources

I. Probable resources—Associated with existing fields—most assured,

- 1) Discovered—unconfirmed: discovered trap, existing production elsewhere in the trap [1]
- 2) Undiscovered: undiscovered trap, productive formation—supply from new pool discoveries within existing field in
 - a) reservoir producing within the same field [2]
 - b) shallower or deeper formation producing elsewhere within same geologic province or sub province [3]

II. Possible resources—New field discoveries associated with productive formations—less assured,

- 1) Similar geologic conditions [4]
- 2) Different geologic conditions: e.g., stratigraphic vs. structural trap [5]

III. Speculative resources—New pool or field discoveries associated with nonproductive formations or nonproductive provinces—most nebulous

- 1) From nonproductive formation in productive province
 - a) new pool [6]
 - b) new field [7]
 - 2) From nonproductive province [8]
-

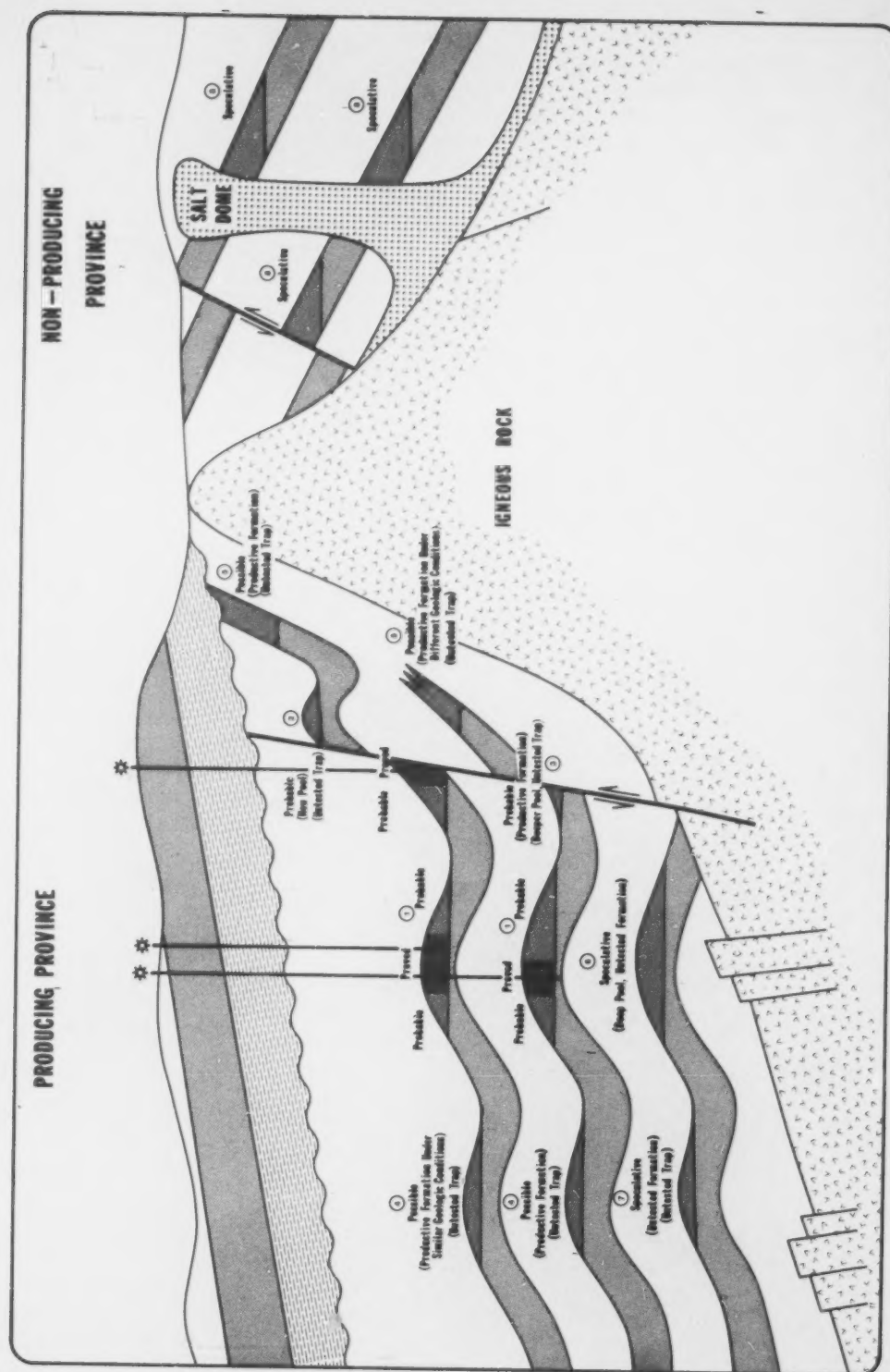


Figure 3. Schematic representation of categories of potential gas resources.

known fields, but they are associated with a productive formation in a productive province. Their occurrence is indicated by a projection of plays or trends of a producing formation into a less well-explored area of the same geologic province or subprovince. The resources are expected to be found from *new field* discoveries, postulated to occur within these trends or plays under both similar [4] and different [5] geologic conditions (i.e., the types of traps and/or structural settings may either be the same or differ in some aspect).

Speculative resources, the most nebulous category, are expected to be found in formations or provinces that have not yet proven to be productive. Geologic analogs are developed in order to ensure reasonable evaluation of these unknown quantities. The resources are anticipated from *new pool* [6] or *new field* [7] discoveries in *formations not previously productive* within a productive geologic province or subprovince and from *new field* discoveries within a geologic province not previously productive [8].

To reiterate, the accuracy of the estimates of potential resources of natural gas is dependent upon geologic conditions and upon knowledge of those conditions and the extent to which the given area has been explored and developed. The consistency and compatibility of the estimates by members of the PGC are maintained by following the estimation guidelines as closely as possible. However, the individual estimator may have to use slight modifications of the considerations and procedures when compiling estimates for each of the three categories because of the particular characteristics applicable to his reporting area.

Estimation of Potential Gas Supply

Geologic provinces and work areas

A total of 89 standard geologic provinces has been defined by the PGC (Figure 4; Plate 1; page 12). The boundaries of these provinces in the conterminous United States correspond closely to the geologic province boundaries established by the Committee on Statistics of Drilling (CSD) of the American Association of Petroleum Geologists. In some instances, adjacent CSD provinces have been combined by the PGC where these provinces have only limited potential for natural gas resources. The province boundaries conform closely to geologic boundaries recognized by the working geologists of the PGC and have the advantage of accessible drilling, discovery and geologic information for the province. Minor changes to province boundaries have also been made where, in the judgment of PGC members, geologic conditions required modification. Provinces for Alaska have been established independently by the PGC on the basis of current understanding of geology and resource potential and do not correspond to provinces established by the CSD. Resource estimates are made for each geologic province by members of the PGC.

For purposes of organization, the PGC is subdivided into seven Area Work Committees that correspond to geographic areas of the country. Each area contains a number of geologic provinces, and each committee is responsible for preparation of the resource estimates for the geologic provinces that fall within that area's limits. Membership for the Area Work Committees is recruited from among the geologists and engineers who are actively engaged in exploration and development of natural gas in the various geologic provinces. Since the judgment of the estimator is the most significant single factor in the preparation of resource estimates, every effort is made to recruit the most knowledgeable experts for membership. Additionally, a separate committee has been formed to prepare a report on resources of natural gas recoverable directly from coal seams. This report is included as a separate chapter in this publication. Although understanding of the nature of the coalbed

methane resource is incomplete and production history is limited, commercial production is taking place and the resource is being recovered. The relative immaturity of the coalbed methane industry and lack of long-term production records make it difficult to prepare estimates of recoverable quantities of gas, however, the chapter summarizes the current state of knowledge.

Estimation procedures

This section presents a brief review of the techniques used by the Potential Gas Committee in preparing estimates of the natural gas resources of the United States. More detail concerning the methodology and its application is contained in the procedures manual of the Committee.¹

The basic technique for estimation of potential gas resources is to compare the factors that control known occurrences of natural gas with factors present in prospective areas. This technique is applied to each of the categories adopted by the PGC. In each case, what is known about the prospective area is evaluated relative to what is known about natural gas accumulations which have been discovered in other parts of the same geologic province or in similar geologic provinces. Natural gas occurrences are related to conditions favoring their formation and accumulation, such as the existence of source rocks, sufficient maturation of organic material, and the presence of reservoir rocks and traps. Studies of producing areas provide information on the productive capacity of particular formations and the average size of accumulations. In its simplest

¹Potential Gas Committee, 1984, Definitions and procedures for estimation of potential gas resources: Gas Resources Studies Number 2, Potential Gas Agency, Colorado School of Mines, Golden, 16 p.



Figure 4. Potential Gas Committee work areas and geologic provinces.

form, the estimate of the potential supply is derived by (1) estimating the volume of potential gas-bearing reservoir rock, (2) multiplying this volume by a yield factor² and (3) discounting to allow for the probability that the traps and/or the accumulations exist. Modifications of the basic technique are necessary to accommodate the variations in amount of information available for prospective areas.

Each estimator considers three separate situations in preparing estimates:

1. Maximum potential resource—The quantity of natural gas which might exist and be recoverable under the most favorable conditions. The probability that such conditions might prevail is assumed to be approximately 10 percent, thus only a 10 percent probability exists that at least this much gas resource is present. This assumes the maximum number of potential traps with favorable source bed and reservoir conditions, the maximum reasonable yield factor, and each trap is filled with recoverable accumulation. Such assumptions would lead to a reasonable estimate of the maximum resource quantity.

2. Minimum potential resource—The existence of the minimum number of traps, the most marginal source beds and reservoir conditions, the minimum reasonable yield factor, and the possibility that many of the traps which might exist would not contain recoverable accumulations of natural gas. In this case, it is assumed that there is approximately a 90 percent probability that at least this much natural gas resource is present. Such assumptions would lead to a reasonable estimate of the minimum resource quantity.

3. Most Likely potential resource—The most reasonable estimate both of the existence of traps and accumulations and the most reasonable assessment of

the source bed, yield factor, and reservoir conditions. These conditions would lead to the most likely estimate of the resource quantity.

Estimates of the maximum, most likely and minimum resource potential are given individually for each geologic province. Most likely resource estimates for each province are summed to derive a total resource potential for each Area and for the entire nation. It is believed that the Committee's estimates represent a distribution such that the most likely estimates correspond closely to the statistical mean. Under these conditions the most likely estimates are additive, and the estimates for provinces can be combined to provide estimates for larger areas.

By considering each of the three situations outlined above, the estimator can best express both the limiting conditions within the geologic region and also the most likely estimate of the resource potential. Estimates prepared by the individual estimators are reviewed periodically at meetings of Area Work Committees and by the entire PGC at the national level, in order that a reasonable degree of consistency and uniformity is maintained.

Limiting Considerations

The estimates presented here are limited to the contiguous United States, Alaska, and adjacent offshore areas. Hawaii, the island territories and their adjacent offshore areas are not included.

PGC Work Areas and geologic provinces for the Lower 48 states are shown in Figure 4 and on Plate 1. Alaskan provinces are shown generally on page 12 and in more detail on a separate plate available on request from the Potential Gas Agency, Colorado School of Mines, Golden, CO 80401, USA for a fee of \$5.00, including shipping within the continental United States.

Drilling depth and water depth limitations

No potential supply of natural gas is included which exists at subsurface depths greater than 30,000

²Yield factors represent the amount of gas expected to be produced from a given unit volume of rock. They are calculated using data from known gas accumulations considered most similar to the one being evaluated. The yield is the volume of discovered gas (i.e., cumulative production plus proved reserves) divided by the volume of productive rock containing the discovered gas. The yield factor applied to any prospective area is adjusted to accommodate variations appropriate to the prospective area.

feet or, in offshore areas, where water depths are in excess of 1,000 meters (3,281 feet), with the exception of the Gulf of Mexico where estimates are included for water depths greater than 1,000 meters in U.S. territorial waters. Separate evaluations are made for the potential supply existing at onshore drilling depths from 0 to 15,000 feet and from 15,000 to 30,000 feet. These subdivisions recognize the greater technological and economic difficulties of recovering resources that exist below drilling depths of 15,000 feet. In offshore areas, estimates are made for the potential existing beneath water depths of 0 to 200 meters (656 feet) and 200 to 1,000 meters (3,281 feet). In the Gulf of Mexico, a separate estimate has been made for water depths greater than 1,000 meters. Estimates for water depths less than 200 meters essentially represent the potential supply that may be recovered from beneath the Continental Shelf, whereas the estimates for water depths of 200 to 1,000 meters essentially represent resources that may be recovered from beneath portions of the Continental Slope. Water depths greater than 1,000 meters represent the outer portion of the Continental Slope and the deep ocean basin area of the Gulf of Mexico.

Estimates made by the Area Work Committees include resources which exist beneath areas presently withdrawn or proposed for withdrawal from exploration and development because of governmental action. Where considerable potential exists beneath these withdrawn areas, it is appropriate that estimates of this potential be made and presented in the narrative portion of the report submitted by each Area Committee.

Economic, technological and policy considerations

Economic, technological and governmental policy considerations taken into account in the Potential Gas Committee's estimate of potential gas supply are related to (1) past production and proved reserves of natural gas, and (2) all wells which would be drilled in the future under the assumed conditions of adequate economic incentives in terms of price/cost relationships and current or foreseeable technology. Fundamental economic considerations—which include but are not limited to prices, costs, rates of take, recovery factors, abandonment pressures, etc.—are inherent in the definition of proved reserves:

“... recoverable in the future from known oil and gas reservoirs under existing economic and operating conditions.”

Some gas that is actually present in known reservoirs is not producible because of unfavorable present or foreseeable price/cost relationships and, therefore, is not included in recoverable reserves. Furthermore, there are other known gas accumulations of such small size that none of the gas can be produced in commercial quantities under “... existing economic and operating conditions.” Such considerations result in proved reserves being somewhat less than the total volumes of gas existing in known reservoirs. These same limitations are applicable to the estimates of potential resources. If a fundamental change in economics or technology occurs, estimates of potential resources will be changed accordingly.

The attribution technique presented in the Estimation of Potential Gas Supply section describes relationships between ultimately recoverable volumes of gas from known occurrences and prospective gas accumulations, after appropriate adjustment for variations in geological and reservoir conditions. The explicit assumptions of adequate but reasonable prices and normal improvements in technology in the definition of potential resources relate to improvements in exploration and production techniques. Adequate prices, normal technological improvements and reasonable governmental policies are required to bring about the drilling necessary to prove the potential resources. These assumed conditions permit estimates of potential resources to be made by the PGC on the basis of relevant past history and experience concerning recovery factors, as well as the size and type of reservoirs which have been found, developed, and produced, without speculating as to future levels of prices and costs.

National Summary Statistics

The following tables summarize the Potential Gas Committee resource estimates on a national basis. Additionally, data have been derived from the Committee on Natural Gas Reserves of the American Gas Association,³ and the Energy Information Administration.⁴

³American Gas Association, 1980, Report of the Committee on Natural Gas Reserves, *in* American Petroleum Institute, American Gas Association, and Canadian Petroleum Association, Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1979 (and earlier years): Washington, DC.

⁴Energy Information Administration, 1988, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1987 Annual Report - from footnote 4: U.S. Department of Energy, Energy Information Administration, Washington, DC, 105 p. ([DOE/EIA-0216(87)] and reports for earlier years).

Table 2. Potential Gas Committee 1988 estimates by Area
(Most likely values--billion cubic feet)

AREA		PROBABLE	POSSIBLE	SPECULATIVE	TOTAL
Atlantic					
Onshore	0-15000'	22,000	7,800	18,600	48,400
	15-30000'	**	400	12,350	12,750
	TOTAL	22,000	8,200	30,950	61,150
Offshore	0-200m	**	**	14,800	14,800
	200-1000m	**	**	650	650
	TOTAL	**	**	15,450	15,450
AREA TOTAL		22,000	8,200	46,400	76,600
North Central					
Onshore	0-15000'	1,750	6,850	10,300	18,900
	15-30000'	**	**	*	*
AREA TOTAL		1,750	6,850	10,300	18,900
Gulf Coast					
Onshore	0-15000'	12,050	15,350	3,450	31,850
	15-30000'	10,700	19,550	12,550	42,800
	TOTAL	22,750	35,900	16,000	74,650
Offshore	0-200m	25,000	36,100	7,800	68,900
	200-1000m	1,500	19,100	9,400	30,000
	>1000m	**	**	30,000	30,000
	TOTAL	26,500	55,200	47,200	128,900
AREA TOTAL		49,250	91,100	63,200	203,550
Mid-Continent					
Onshore	0-15000'	29,000	38,350	26,100	93,450
	15-30000'	16,800	23,300	5,500	45,600
AREA TOTAL		45,800	61,650	31,600	139,050
Rocky Mountain					
Onshore	0-15000'	29,950	34,250	13,650	77,850
	15-30000'	14,050	20,750	7,100	41,900
AREA TOTAL		44,000	55,000	20,750	119,750
Pacific					
Onshore	0-15000'	1,350	5,450	6,000	12,800
	15-3000'	200	750	500	1,450
	TOTAL	1,550	6,200	6,500	14,250
Offshore	0-200m	50	4,750	1,750	6,550
	200-1000m	50	4,200	4,050	8,300
	TOTAL	100	8,950	5,800	14,850
AREA TOTAL		1,650	15,150	12,300	29,100
TOTAL LOWER 48 STATES		164,450	237,950	184,550	586,950
Alaska					
Onshore	0-15000'	6,350	16,400	27,700	50,450
	15-30000'	**	**	*	*
	TOTAL	6,350	16,400	27,700	50,450
Offshore	0-200m	2,400	12,700	50,350	65,450
	200-1000m	**	**	2,650	2,650
	TOTAL	2,400	12,700	53,000	68,100
AREA TOTAL		8,750	29,100	80,700	118,550
TOTAL UNITED STATES		173,200	267,050	265,250	705,500
COAL BED METHANE					90,100
GRAND TOTAL UNITED STATES					795,600

* Negligible quantity of natural gas estimated

** Production has not been established; no Probable or Possible resource exists

Table 3. Potential Gas Committee 1988 estimates -- total United States
(Most Likely Values--billion cubic feet)

	PROBABLE	POSSIBLE	SPECULATIVE	TOTAL
ONSHORE (drilling depth)				
Lower 48 States				
less than 15000 feet	96,100	109,050	78,100	283,250
15000 to 30000 feet	41,750	64,750	38,000	144,500
Alaska				
less than 15000 feet	6,350	16,400	27,700	50,450
15000 to 30000 feet	**	**	*	**
TOTAL ONSHORE	144,200	190,200	143,800	478,200
OFFSHORE (water depth)				
Lower 48 States				
less than 200 meters	25,050	40,850	24,350	90,250
200 to 1000 meters	1,550	23,300	14,100	38,950
greater than 1000meters	**	**	30,000	30,000
Alaska				
less than 200 meters	2,400	12,700	50,350	65,450
200 to 1000 meters	**	**	2,650	2,650
TOTAL OFFSHORE	29,000	76,850	121,450	227,300
TOTAL LOWER 48 STATES	164,450	237,950	184,550	586,950
TOTAL ALASKA	8,750	29,100	80,700	118,550
TOTAL UNITED STATES	173,200	267,050	265,250	705,500
COALBED METHANE				90,100
GRAND TOTAL UNITED STATES				795,600

*Negligible quantity of natural gas estimated

** Production has not been established; no Probable or Possible resource exists

Table 4. Comparison of estimates of ultimately recoverable volumes of natural gas in the United States (trillion cubic feet)

Total United States						
Year	Cumulative Production (1)	Proved Reserves (2)	Potential Resources (3)	Coalbed Methane (3)	Estimated Future Supply*	Ultimately Recoverable Resource**
1968	345	287	1227		1514	1859
1970	387	291	1178		1469	1856
1972	432	266	1146		1412	1844
1974	477	237	1146		1383	1860
1976	515	216	948		1164	1679
1978	553	200	1019		1219	1772
1980	596	199	913		1112	1708
1982	632	202	876		1078	1710
1984	665	196	784		980	1645
1986	697	193	739		932	1629
1988	729 est.	187 est.	706	90	983	1712
Lower 48 states						
Year	Cumulative Production (1)	Proved Reserves (2)	Potential Resources (3)	Coalbed Methane (3)	Estimated Future Supply*	Ultimately Recoverable Resource**
1966	300	286	690		976	1276
1968	345	282	795		1077	1422
1970	388	260	851		1111	1499
1972	432	235	780		1015	1447
1974	476	205	780		985	1461
1976	514	184	748		932	1446
1978	532	177	830		1007	1539
1980	571	163	768		931	1502
1982	613	169	742		911	1524
1984	662	163	647		810	1472
1986	693	160	620		780	1473
1988	725 est.	154 est.	587	90	831	1556

(1) Cumulative production figures derived from A.G.A. Committee on Natural Gas Reserves, plus annual production reports from US Department of Energy, Energy Information Administration. Cumulative production shown for 1988 is an estimate only.

(2) Proved reserves derived from reports of the A.G.A. Committee on Natural Gas Reserves for years through 1979. Proved reserves for years from 1980 on are derived from reports of US Department of Energy, Energy Information Administration. Proved reserves shown for 1988 are 1987 estimates.

(3) Potential resources and coalbed methane from estimates of Potential Gas Committee.

*Proved reserves + potential resources + coalbed methane. **Future supply + cumulative production.

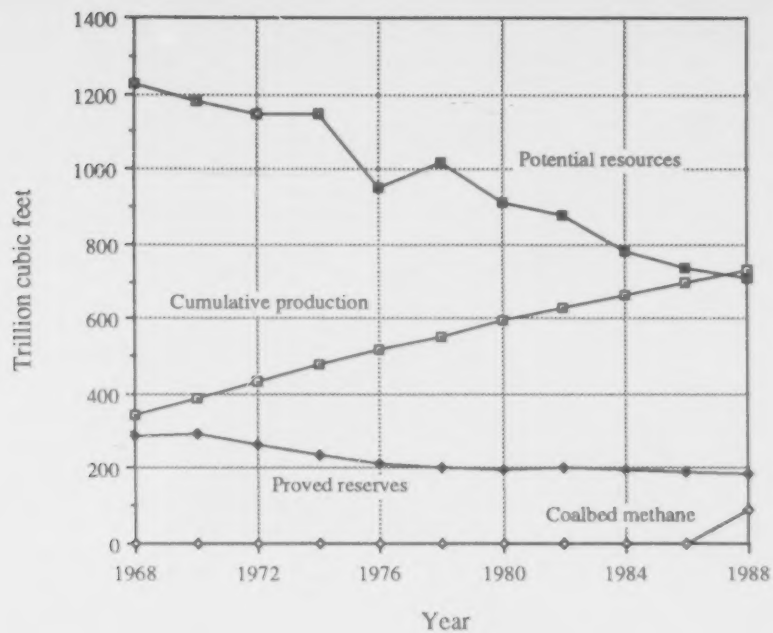


Figure 5. Biennial estimates of cumulative production, proved reserves and potential resources of natural gas in the total United States.

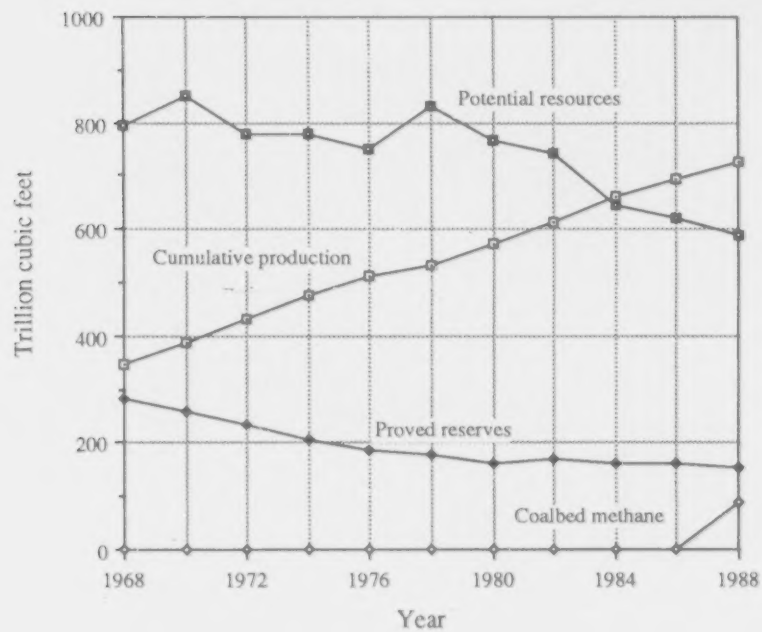


Figure 6. Biennial estimates of cumulative production, proved reserves and potential resources of natural gas in the Lower 48 states

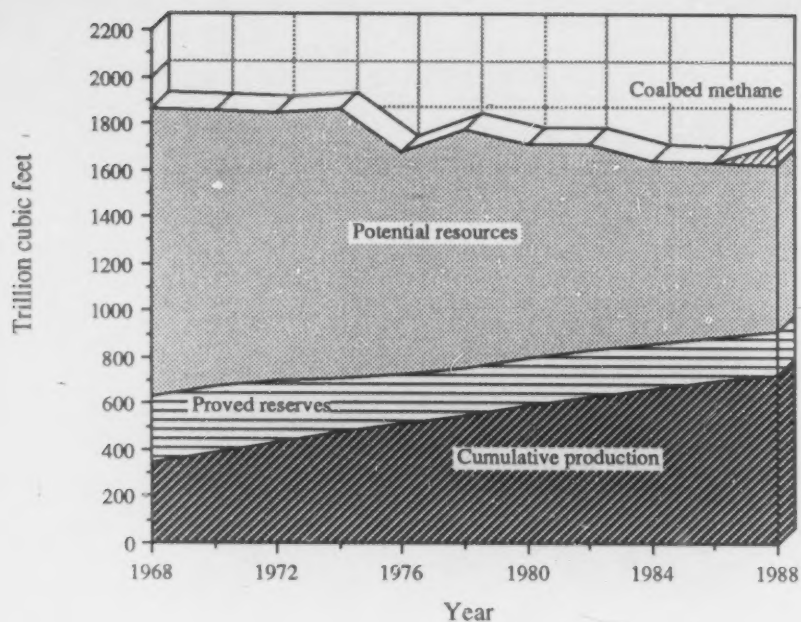


Figure 7. Estimates of ultimately recoverable resources of natural gas in the total United States.

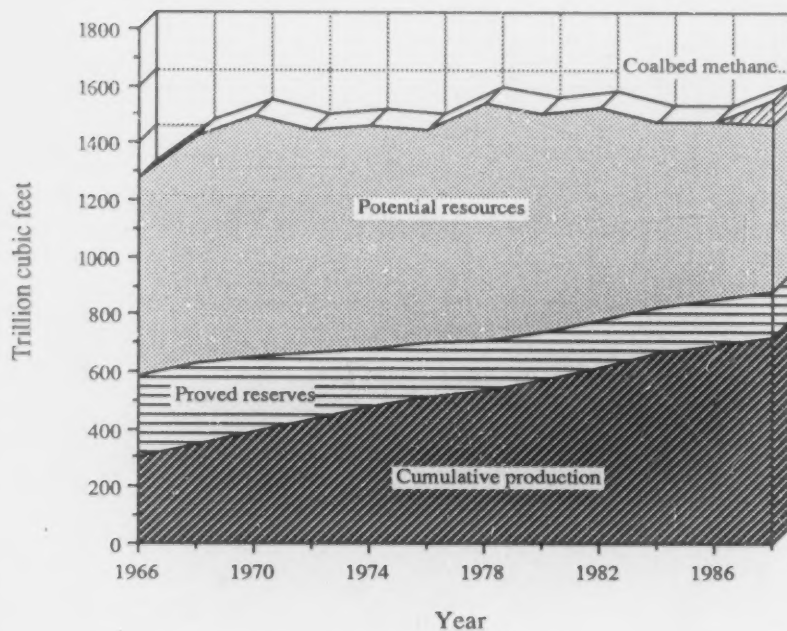


Figure 8. Estimates of ultimately recoverable resources of natural gas in the Lower 48 states.

Table 5. Comparison of estimates of potential resources of natural gas
from Potential Gas Committee reports
(Most Likely Values--trillion cubic feet)

	PROBABLE RESOURCES	POSSIBLE RESOURCES	SPECULATIVE RESOURCES	TOTAL RESOURCES
TOTAL UNITED STATES				
As of 12-31-68	260	335	632	1,227
As of 12-31-70	257	387	534	1,178
As of 12-31-72	266	384	496	1,146
As of 12-31-76	215	363	345 to 395	923 to 973
As of 12-31-78	199	399	421	1,019
As of 12-31-80	193	358	362	913
As of 12-31-82	192	355	329	876
As of 12-31-84	185	293	306	784
As of 12-31-86	163	298	278	739
As of 12-31-88	173	267	265	706
LOWER 48 STATES				
As of 12-31-66	300	210	180	690
As of 12-31-68	238	317	240	795
As of 12-31-70	218	326	307	851
As of 12-31-72	212	290	278	780
As of 12-31-76	192	318	188 to 238	698 to 748
As of 12-31-78	186	359	285	830
As of 12-31-80	185	329	254	768
As of 12-31-82	184	326	232	742
As of 12-31-84	176	264	207	647
As of 12-31-86	154	269	197	620
As of 12-31-88	164	238	185	587

Table 6. Comparison of estimates, 1986 and 1988, by Area
(Most Likely Values--billion cubic feet)

AREA	PROBABLE		POSSIBLE		SPECULATIVE	
	1986	1988	1986	1988	1986	1988
ATLANTIC						
Onshore	21,950	22,000	8,130	8,200	34,430	30,950
Offshore	**	**	**	**	15,450	15,450
TOTAL	21,950	22,000	8,130	8,200	49,880	46,400
NORTH CENTRAL						
TOTAL	187	1,750	4,113	6,850	10,323	10,300
GULF COAST						
Onshore	20,350	22,750	37,120	35,900	16,950	16,000
Offshore	25,225	26,500	60,235	55,200	16,490	47,200
TOTAL	45,575	49,250	97,355	91,100	33,440	63,200
MID-CONTINENT						
TOTAL	47,600	45,800	90,800	61,650	62,100	31,600
ROCKY MOUNTAIN						
TOTAL	36,551	44,000	53,283	55,000	25,466	20,750
PACIFIC						
Onshore	1,545	1,550	6,600	6,200	6,900	6,500
Offshore	237	100	8,913	8,950	8,828	5,800
TOTAL	1,782	1,650	15,513	15,150	15,728	12,300
TOTAL LOWER 48 STATES	153,645	164,450	269,194	237,950	196,937	184,550
ALASKA						
Onshore	6,590	6,350	16,400	16,400	27,690	27,700
Offshore	2,400	2,400	12,700	12,700	53,000	53,000
TOTAL	8,990	8,750	29,100	29,100	80,690	80,700
TOTAL UNITED STATES	162,635	173,200	298,294	267,050	277,627	265,250

**Production has not been established; no Probable or Possible resource exists.

POTENTIAL GAS COMMITTEE

NATURAL GAS RESOURCE ESTIMATES

(December 31, 1988)

The following pages comprise the Potential Gas Committee's estimate of potential natural gas resources for the United States as of December 31, 1988. The estimates are presented by Work Area and by geologic province within each Work Area.

A summary of the geology and natural gas resource potential for each geologic province is presented in order to provide the reader with brief background information about the province. This summary is not intended to be an exhaustive treatment, but rather to cover the fundamental geologic setting and its significance relative to natural gas occurrence. Information has been derived from a number of sources, especially Landes¹ and Cram.² Additional information has been provided in personal communication from members of the Potential Gas Committee.

Generalized stratigraphic sections have been provided for a number of the geologic provinces, especially those with significant natural gas potential. These stratigraphic sections are not necessarily accurate in all details, but they should serve to orient the reader concerning the stratigraphic position and age of reservoir and source rocks mentioned in the text. In addition to the sources listed for the geologic summaries, information for the stratigraphic sections has been derived from the published stratigraphic sections of the COSUNA project.³

Stratigraphic sections have been annotated to indicate those formations presently or potentially productive of natural gas. Formations which are currently productive of gas in commercial quantities, or have been productive of gas in the past, are indicated by an asterisk (*). Formations which, in the judgment of PGC members, have the potential to be productive of natural gas, but which are not currently productive within the province, are indicated by a pound sign (#). Other formations are not considered potentially productive.

¹Landes, K. K., 1970, *Petroleum Geology of the United States*: Wiley-Interscience, New York, 571 p.

²Cram, I. H., ed., 1971, *Future Petroleum Provinces of the United States—Their Geology and Potential*: American Association of Petroleum Geologists, Memoir 15, Tulsa, 1,496 p.

³Correlation of Stratigraphic Units of North America (COSUNA) Project: American Association of Petroleum Geologists, Tulsa.



ATLANTIC AREA

The only geologic provinces of the Atlantic Area currently productive of natural gas are the Appalachian basin and the Black Warrior basin. Other provinces which have potential for future resource development are the New England and Adirondack uplift province, the Atlantic Coastal basin, the Piedmont-Blue Ridge province, the South Georgia-Peninsular Florida sedimentary province, and the Atlantic and West Florida Offshore provinces.

P-100, NEW ENGLAND PROVINCE AND ADIRONDACK UPLIFT

This province includes the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, Vermont and 14 counties in eastern New York State. No production of oil or natural gas has been established in this area. Sedimentary rocks in the area are predominantly of Paleozoic age, reaching a thickness of 15,000 to 20,000 feet. Additionally, there is a thick sequence of sedimentary rocks of Triassic age in the Connecticut Triassic basin. All postulated natural gas potential is located in the Connecticut Triassic basin and in the Eastern Thrust Belt which extends into eastern New York and western Vermont. Potential reservoir rocks in the Eastern Thrust Belt are of Ordovician and Cambrian age and occur both in the area of surface exposure of Paleozoic rocks (west) and the area in which the Paleozoic rocks are concealed beneath thrust older rocks (east).

P-110, ATLANTIC COASTAL BASIN

This province includes the entire state of Delaware and portions of New Jersey, Maryland, Virginia, North Carolina and South Carolina. No production of oil or gas has been established to date. The province is bordered generally on the west by the Appalachian and Blue Ridge Mountains and includes an area of over 108,000 square miles. Sedimentary rocks range in age from Triassic(?) or Jurassic to Quaternary. Recent geophysical surveys and deep drilling have established that there are greater thicknesses of sedimentary rocks in this province than previously thought, greatly in excess of previous estimates of 10,000 feet. Potential for natural gas is believed to be limited largely to the Triassic basins, both those in which Triassic rocks are exposed at the surface and those in which younger sedimentary rocks cover the Triassic. There is also some potential in the deeper formations in the coastal areas of North and South Carolina.

P-120, APPALACHIAN BASIN

The Appalachian basin province covers an area of over 180,000 square miles in portions of the states of New York, Pennsylvania, New Jersey, West Virginia, Virginia, Maryland, Ohio, Kentucky, Tennessee, Georgia and Alabama. Its eastern border includes the Appalachian Mountains and it extends westward to the Cincinnati arch and the Nashville dome. Sedimentary rocks in the basin exceed thicknesses of 30,000 feet in places, and potential reservoir rocks range in age from Cambrian to Pennsylvanian.

Although several hundred thousand wells have been drilled in the Appalachian basin, most of them have been relatively shallow (less than 5,000 feet) and concentrated along narrow producing trends. In the entire basin, only eleven wells have been drilled to a depth deeper than 15,000 feet. Only 10-15% of the possible hydrocarbon-producing sedimentary rocks have been tested and, in terms of exploration, the basin is relatively young.

P-110, ATLANTIC COASTAL BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	North	South
Cenozoic		
Quaternary		Holocene-Pleistocene deposits
Tertiary		
Pliocene		Yorktown Fm.
Miocene	Kirkwood Fm.-St. Marys Fm.-Choptank Fm.-Calvert Fm.-Hawthorn Fm.	Pungo R. Fm.
Oligocene		River Bend Fm.-Cooper Fm.
Eocene	Deal Fm. Nanjemoy Fm.-Pamunkey Gp.-Castle Hayne Fm.-Santee Ls.-	-Huber Fm.
		Black Mingo Fm.
Paleocene	Hornerstown Fm.	
Mesozoic		
Cretaceous		
Upper	Monmouth Gp.-Mt. Laurel Sd.	unit "A" Peedee Fm.
	Matawan Fm.	unit "B" Black Creek Fm.
	Magothy Fm.	unit "C"
	Raritan Fm.	unit "D" Middendorf Fm.
		unit "E" Cape Fear Fm.
		unit "F"
#Lower		unit "G"
	Potomac Gp.(Fm.)	unit "H"
#Jurassic (?)		
Triassic (?)	Newark Group	unnamed red beds
Pre-Mesozoic basement		
	# Potentially productive	

Probable resources are expected to be found mostly in field extensions, infill drilling and connecting old fields. Possible resources are expected to be found in fields ranging in size from 5 to 500 Bcf with most of them being in the 15 to 50 Bcf range. Speculative resources are expected to be found in fields ranging in size from 50 to 1,000 Bcf with the most likely size being between 300 and 500 Bcf.

Reservoir rocks. Both detrital rocks and carbonates form potential reservoirs, and production has already been established from most potential reservoirs in at least some part of the basin. Production from Mississippian-Pennsylvanian, Devonian, Silurian, middle Late Ordovician and Cambro-Ordovician units

is located, generally, along long, regional anticlinal trends that are oriented in a northeast-southwest direction. Fracturing plays an important role in the deeper reservoirs.

Traps. Stratigraphic, structural and combination traps are all abundant. Lenses, reefs and porosity variations are most important in Silurian and Mississippian reservoirs. Truncations are characteristic of Silurian-Ordovician strata. Production from widespread Devonian shales is closely related to regional fracturing patterns. Shales also form traps and seals for contained sandstone lenses. Anticlines and faulted anticlines form major traps for hydrocarbons in Devonian and Carboniferous reservoirs.

P-120, APPALACHIAN BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	North	South
Paleozoic		
Permian		*Dunkard Fm.
Pennsylvanian		*Monongahela Fm.
	Llewellyn Fm.	*Conemaugh Fm.
		*Allegheny Fm.
		*Pottsville Ss.
Mississippian	*Mauch Chunk Fm.	Kanawha Fm.
	*Greenbrier Ls.	Parkwood-Pennington Fm.
	*Pocono Group	Floyd Shale-Bangor Ls.
Devonian	*Catskill Fm.-*Chemung Fm.	*Fort Payne Chert
	*Hamilton Group Millboro Sh.	#Chattanooga Sh.
	*Onondaga Ls.	*Huntersville Chert
	*Oriskany Ss.	Frog Mountain Ss.
		*Helderberg Group
Silurian	*Bass Islands Group	
	Salina Group	Tonoloway Fm.
	*Lockport Fm.	McKenzie Fm.
		*Keefer Ss.
		Rose Hill Fm.
Ordovician	*Medina-Albion-Tuscarora Fm.	*Clinton Fm.
	*Queenston Fm./Juniata Fm.	Clinch-Brassfield Fm.
	Utica Shale Reedsville-Martinsburg Fm.	Sequatchie Fm.
	*Trenton-Black River Gps.	High Bridge-Chickamauga-Stones R. Group
Camb./Ordo.	*Beekmantown Group	*Knox Group
Cambrian		*Copper Ridge Fm.
	#Potsdam Ss.	Elbrook-Conasauga Group
		Nolichucky Sh.
		#Rome Fm.
		Shady Dolo.
Precambrian	basal formations	
	* Currently producing # Potentially productive	

Potential source rocks. Probable source rocks for both oil and gas range from the thermally moderately mature to severely altered mid-Cambrian Rome Shale gas generators to the mid- to late-Mississippian Big Lime Formation which is a thermally moderately mature to immature source for both oil and gas. Surface seeps, tar sands and solid hydrocarbon exposures are all known from the province.

Producing trends. The central portion of the basin is basically one giant gas field, extending more than 500 miles along a northeast-southwest trend and 50 to 75 miles wide. A similar trend farther to the west parallels the giant field; here, gas production is generally more scattered in thousands of fields. This western trend defines the limit of the Appalachian basin in the west. The vast majority of the counties included within the limits of the Appalachian basin have at least some gas production. The Cambro-Ordovician Rome Formation is productive of both gas and oil at depths of almost 15,000 feet, whereas the Mississippian Berea sandstones and siltstones produce from the surface to depths of 6,100 feet.

Coalbed methane. The presence of extensive coal deposits of Pennsylvanian age in the Appalachian basin makes this one of the prime areas in the United States for the development and production of methane from coal beds. Although commercial development of the resource in this basin has lagged behind that of the Black Warrior basin of Alabama or the San Juan basin of New Mexico and Colorado, current interest indicates a substantial increase in potential for development in the near term. This will be in addition to production from commercial sandstone reservoirs and from Devonian shales. Coal degasification wells associated with mining operations have existed in the province for many years, but the commercial recovery of the gas from these wells has been limited. The Big Run gas field, located in Wetzel County, northwestern West Virginia, has produced methane continuously since 1932 from an interval that includes the Pittsburgh coal bed. Since that time, the field has produced an estimated 2.3 Bcf of gas; one well made more than 200 MMcf of gas in about 36 years. Estimates place the in-place coalbed methane resource for the northern portion of the Appalachian basin at approximately 61 Tcf and that for the central portion from 5 to 48 Tcf. The most likely estimate of the recoverable resource at this time is approximately 25 Tcf.

P-130, PIEDMONT—BLUE RIDGE PROVINCE

This province covers portions of the states of Alabama, Georgia, South Carolina, North Carolina, Tennessee, Virginia, Maryland, Delaware, Pennsylvania and New Jersey, and includes an area of approximately 94,000 square miles. The province lies within the Appalachian and Blue Ridge Mountain regions and the Eastern, or Blue Ridge, Overthrust Belt is the major tectonic feature. Sedimentary rocks within the province are in excess of 30,000 feet thick and range in age from Precambrian upward, but are mainly of early Paleozoic age. No oil or natural gas production has been established in this province to date.

Reservoir rocks. Potential reservoir rocks are of Cambrian through Mississippian age. They are concealed by metamorphic rocks and granites which have been thrust from the east westward across the younger sedimentary rocks. Suspected important reservoir formations include the Cambro-Ordovician Knox Dolomite, the early Cambrian Rome Formation (shale, sandstone and dolomite) and the Precambrian to Cambrian Chilhowee Group (fractured shales).

Traps. Major anticlines within the concealed sedimentary section are interpreted from seismic cross sections and are anticipated to be the principal trapping mechanism.

Potential source rocks. The mid-Ordovician and mid-Cambrian shales are postulated to be potential source rocks for natural gas and are thermally mature. Gas shows have been reported from similar rocks to the west.

P-140, S. GEORGIA-PENINSULAR FLORIDA,
P-915 AND P-916, W. FLORIDA OFFSHORE, SHELF AND SLOPE
Generalized Stratigraphic Section

AGE	FORMATION	
	North	South
Cenozoic		
Miocene	Hawthorne Group	Hawthorne Group
Oligocene	unnamed limestone	Suwanee Fm.
Eocene	unnamed limestone	Ocala Fm.
	unnamed limestone	Avon Park Fm.
	unnamed limestone	Oldsmar Fm.
Paleocene	#Cedar Keys Fm.	#Cedar Keys Fm.
Mesozoic		
Cretaceous		
Upper	unnamed sand and Pine Key Fm. Atkinson Fm.	Pine Key Fm. Atkinson Fm.
Lower	unnamed sandstone and shale	Marquesas Supergroup Big Cypress Group #Dollar Bay Fm. Gordon Pass Fm. Marco Junction Fm. Ocean Reef Group Rattlesnake Hammock Fm. Lake Trafford Fm. *Sunniland Ls. Glades Group Punta Gorda Anhydrite Abel Mbr. Twelve Mile Mbr. West Felda Sh. #Lehigh Acres Fm. Pumpkin Bay Fm. Bone Island Fm. Wood River Fm. unnamed volcanic complex unnamed volcanic complex

*Currently producing
#Potentially productive

P-140, SOUTH GEORGIA— PENINSULAR FLORIDA SEDIMENTARY PROVINCE

This province covers the southern half of Georgia and most of the State of Florida with the exception of the Florida Panhandle. It is bordered on the north by the Appalachian Mountain System. The major tectonic elements include the Southeast Georgia Embayment, the northeastern portion of the Appalachicola basin, and the South Florida basin. Sedimentary rocks reach a maximum thickness of 15,000 feet. Production of oil and associated/dissolved natural gas has been established in southern Florida, but the major natural gas production in Florida is located outside this province in the Florida Panhandle (Province P-300).

Reservoir rocks. Sedimentary rocks in the province range in age from Early Cretaceous to Tertiary and include limestones, dolomites and sandstones. Reservoir rocks for oil and associated/dissolved gas are principally Early Cretaceous limestones at depths of up to 9,000 feet.

Traps. Changes in porosity and permeability within the carbonate reservoir rocks, possibly associated with folds, are the principal trapping mechanisms.

Potential source rocks. Potential source rocks for gas and oil include the thermally immature Cedar Keys Formation (Paleocene) and the moderately mature Sunniland Limestone (Early Cretaceous).

P-150, BLACK WARRIOR BASIN

The Black Warrior basin is a triangular-shaped area located in northeastern Mississippi and northwestern Alabama. The basin extends over approximately 21,000 square miles. The Black Warrior basin is bounded on the north by the Nashville and Ozark domes, on the southeast by the Appalachian tectonic belt and on the southwest by the central Mississippi deformed belt. The sedimentary section is thicker than 20,000 feet in the deeper portion of the basin. The Black Warrior basin is currently a major producing area for natural gas, most of which is found above 6,000 feet, with only minor accumulations of oil. Recovery of natural gas associated with coal seams is becoming increasingly important.

In terms of exploration maturity, the Black Warrior basin can be divided into three areas: 1) the shallow northern and eastern portions of the basin, an area that is sparsely drilled and is considered to be immature with the potential for discovery of a number of fields of relatively small size because of both stratigraphy and depth; 2) the central portion of the basin, which is considered to be in early maturity, and holds the potential for several small- and moderate-size new field discoveries and a large number of field extensions; and 3) the southern, deeper portion of the basin which holds the potential for some intermediate- and large-size field discoveries. Sedimentary rocks in this area exceed 20,000 feet in thickness. Only seven wells have been drilled to a depth greater than 12,000 feet in the entire Black Warrior basin, and only four wells have been drilled below 15,000 feet. The interaction of structure, stratigraphy and diagenesis in the deeper portion of the Black Warrior basin is relatively unknown and will control the size and number of fields discovered.

Reservoir rocks. Production in the Black Warrior basin is primarily from Paleozoic clastics of the Mississippian Chester series. The sandstones of the Pennsylvanian Pottsville series also produce some hydrocarbons. Potential reservoir rocks range from Precambrian to Pennsylvanian age and consist of sandstones, limestones, dolomite and chert.

Traps. Hydrocarbon traps in the Black Warrior basin are primarily combination traps involving anticlines, faulted anticlines, high-angle normal faults and stratigraphy. Channel and bar sandstones provide stratigraphic traps in the Chester and Pottsville series.

P-150, BLACK WARRIOR BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	NE Mississippi	NW Alabama
Cenozoic		
Paleocene	Porters Creek Clay	
Mesozoic	Clayton Fm.	
Cretaceous		
Upper	Prairie Bluff Chalk Owl Creek Fm. Ripley Fm. Demopolis Chalk Mooreville Chalk -- Coffee Sand Eutaw Fm. Tuscaloosa Group	
Lower	unnamed sandstone and conglomerate	
Paleozoic		
Pennsylvanian	*Pottsville Fm.	*Pottsville Fm.
Mississippian	*Chester Series #Parkwood Fm. Floyd Sh.	Bangor Ls. Hartselle Ss. Pride Mountain Sh. Monteagle Ls. #Tuscumbia Ls.
Devonian	#Tuscumbia Ls. #Fort Payne Chert "Devonian Chert" (Arkansas Novaculite)	#Chattanooga Sh.
Silurian	unnamed cherty carbonate rocks	Silurian undifferentiated
Ordovician	Sequatchie Fm.	Sequatchie Fm. Maysville Group Nashville Group Stones River Group #Knox Group Ketona Dolo. Conasauga Formation Rome Fm.
Cambro-Ordovician	Chickamauga Group	
Cambrian	#Knox Group unnamed pre-Knox carbonates unnamed sandstone	
	*Currently producing #Potentially productive	

Stratigraphic traps usually have a structural component. Porosity variations in the carbonate sequences provide potential traps for hydrocarbons alone or in combination with structure and faulting.

Potential source rocks. The Mississippian Chester series is thermally mature to very mature and provides sources for both gas and oil. The thermally mature Pennsylvanian Pottsville series and the mature to very mature Ordovician Black River group would probably be sources primarily for gas.

Coalbed methane. The Lower Pennsylvanian Pottsville Formation is the coal-bearing unit in the basin, containing upwards of 40 net feet of high-rank coal in the area of present drilling activity, at depths from the surface to more than 3,500 feet. The four major, or target, coal groups in the basin are, in descending order, the Cobb, Pratt, Mary Lee, and Black Creek. The east-central part of the basin contains the highest rank coal, low- to medium-volatile bituminous, with in-situ gas contents ranging from approximately 350 to 600-plus cubic feet/ton below a depth of ± 800 feet.

The eastern Black Warrior Basin contains all the established coalbed methane, or coal degasification, fields in the state. More than 500 coalbed methane wells have been drilled in the Black Warrior Basin since 1980, with cumulative production in excess of 60 Bcf gas which amounts to more than 25 percent of all the gas—the rest being chiefly from Mississippian-age sandstones—produced to date in the basin. More than 1,000 coalbed methane wells are expected to be producing in the basin by the end of 1989. The five active coal degasification fields in the Black Warrior Basin currently are producing more than 58 MMcf gas/day; more than 90 percent of the production is derived from Brookwood and Oak Grove fields. Annual coalbed methane production in the basin has risen rapidly from approximately 5 MMcf in 1980 to an estimated 22 Bcf in 1988.

To date, most of the produced gas has been derived from coal beds in the Mary Lee Group, at depths varying from 1,000 to 3,200 feet. Although most of the wells drilled to date have opened only one or two coal beds to production, the trend now is toward multiple-zone completions, where each target coal bed is selec-

tively stimulated through staged hydraulic fracture treatments (mainly sand-water). Average production currently is approximately 150 Mcf/day/well.

It is estimated that the four main target coal groups in the basin contain 19.8 Tcf gas in-place; nearly 40 percent of this is in the Black Creek Group, the deepest of the four. The eastern Black Warrior Basin is estimated to contain at least 8 Tcf of recoverable coalbed methane resources.

P-910 AND P-911, ATLANTIC OFFSHORE, SHELF AND SLOPE

These provinces cover the entire Atlantic offshore area of the United States. Major tectonic features include the Yarmouth arch, Georges Bank basin, Baltimore Canyon Trough, Southeast Georgia Embayment, the Carolina trough and platform, Blake Plateau basin, South Florida-Bahamas basin, and the Peninsular arch of Florida. No natural gas or oil production has been established in the province, although the existence of moderate quantities of gas has been established in at least one area. The accumulation of gas discovered was not sufficient to warrant installation of production facilities. Even though results to date have not been encouraging, numerous concepts and plays remain unevaluated and present some possibility for the existence of natural gas resources. Considering the size of the Atlantic offshore area and the sparsity and uneven distribution of wells, the province must still be considered immature from the standpoint of exploration. If production is established, the fields would have to be intermediate to large size in order to justify commercial development.

Potential reservoir rocks. Sedimentary rocks, mainly of Mesozoic to Tertiary age, are 30,000 feet or more thick. Sandstones and limestones are the major potential reservoir rocks. Limestones are more important in the southern portion of the province and perhaps are more important in the farther offshore areas of the Slope Province.

Traps. A large variety of trapping mechanisms has been postulated to occur, including most principal types of both stratigraphic and structural traps. Carbonate environments, including reefs if present, could include stratigraphic traps due to reef structures and permeability changes. Truncations and pinchouts may be related to some clastic reservoirs. Salt domes are also believed to be present. Structural traps may include both faults and folds.

Potential source rocks. Potential source rocks in the central portion of both provinces are anticipated to be more favorable for natural gas generation than for oil. Prospects for oil generation, along with gas, are more favorable in the northern (Georges Bank) and southern (Southeast Florida Shelf) regions.

P-915 AND P-916, WEST FLORIDA OFFSHORE, SHELF AND SLOPE

The western Florida shelf extends about 150 miles into the Gulf of Mexico. Many of the stratigraphic units of onshore peninsular Florida extend into this offshore area. Cretaceous and Tertiary rocks comprise the majority of the 25,000-30,000 feet of sediment in this area. Carbonate rocks are the major constituent in most of the province. Clastic rocks were deposited in the north. Probability is good for continuation of trends from the eastern part of the Gulf Coast Province and the panhandle region of Florida; additionally, trends which are productive predominantly of oil in south Florida

may also extend offshore and include some natural gas resources. No hydrocarbons are presently being produced in the province. The west Florida offshore area is extremely large and there is virtually no information available from drilling which is applicable to these provinces. If natural gas production is established in the area, it would be anticipated that the fields would be intermediate to large size.

Potential reservoir rocks. The southern part of the province, which lies in the South Florida basin, appears to offer prospects for large-scale production. The Lehigh Acres Formation (Lower Cretaceous) is the best prospect because of the thick and highly porous Brown Dolomite zone in the Twelve Mile Member. The Sunniland Formation, which is productive onshore, will not prove economically feasible offshore unless it has a thicker porous section than is found onshore. Other formations which are of lowermost Cretaceous and upper Jurassic age may prove productive, but to date the porosity and geochemistry found in these formations onshore have not been favorable.

In the northern portion of the province, there is potential for the extension offshore of the productive trends of southern Mississippi, southern Alabama and northwestern Florida. Possible reservoir units in the area are the Upper Cretaceous Tuscaloosa Formation, the Lower Cretaceous Hosston Formation, and the Upper Jurassic Smackover Formation.

Traps. Possible trapping mechanisms include reefs in the Upper Cretaceous and porosity changes in carbonate and sandstone facies. Anticlines, faulted anticlines and salt domes may exist.

P-910 and P-911, ATLANTIC OFFSHORE, SHELF AND SLOPE
Generalized Stratigraphic Section

AGE	FORMATION	
	NORTH	SOUTH
Cenozoic	Pleistocene	Laurentian Fm.
	Pliocene-Miocene	unnamed sands, silt and clay
	Oligocene-Eocene- Paleocene	unnamed mudstone and chalk
Mesozoic	Upper Cretaceous	unnamed siltstone and shale
	Lower Cretaceous	unnamed sandstone shale and limestones
	Jurassic	evaporites
	Triassic	unnamed sandstone siltstone, shale
Paleozoic and Precambrian	metamorphic complex	

Table 7. Estimated resources of natural gas for provinces of the Atlantic Area, December 1988 (billion cubic feet)

PROVINCE	ONSHORE		OFFSHORE		PROBABLE		POSSIBLE		SPECULATIVE	
	depth	Min.	M. likely	Max.	Min.	M. likely	Max.	Min.	M. likely	Max.
P-100, New England and Adirondack uplift	0-15,000'							*	650	1,850
P-110, Atlantic Coastal basin	15-30,000'							*	*	*
P-120, Appalachian basin	0-15,000'	15,000	21,550	52,600	3,950	7,500	24,600	5,550	14,650	51,400
P-130, Piedmont-Blue Ridge province	0-15,000'							820	5,000	16,700
P-140, South Georgia-Peninsular Florida	15-30,000'							500	2,050	6,000
P-150, Black Warrior basin	0-15,000'	160	450	850	100	300	650	920	4,550	11,000
P-910, Atlantic shelf	15-30,000'							*	350	950
P-911, Atlantic slope								*	500	1,450
P-915, West Florida shelf								*	450	1,000
P-916, West Florida slope								*	2,300	3,300
TOTAL, onshore								*	13,200	33,000
TOTAL, onshore, all depths								*	1,600	4,000
TOTAL, offshore								*	650	6,000
TOTAL, offshore, all depths								*	18,600	
GRAND TOTAL FOR AREA								*	12,350	
								*	30,950	
								*	14,800	
								*	650	
								*	15,450	
								*	46,400	

*Negligible quantity of natural gas estimated.



NORTH CENTRAL AREA

The estimated resource potential for the North Central area in the Probable and Possible categories occurs entirely in the Michigan basin. Potential resources in the Speculative category are also estimated to occur in the Michigan basin and, in addition, are postulated for the Cincinnati arch province, the Illinois basin, the Upper Mississippi Embayment and the Forest City-Cherokee basins.

The Michigan basin has good exploratory potential for both structural and stratigraphic traps having small- to intermediate-size accumulations of gas. One or more giant fields are possible. The deep Cambro-Ordovician formations are now being tested in the basin. The evaluation of new data has resulted in an increase in the most likely estimate of Potential resources for the Michigan basin.

The Cincinnati arch province is generally well explored, but has the potential of the occurrence of small accumulations of either structurally or stratigraphically trapped resources. The Illinois basin is a maturely explored oil basin, and potential gas accumulations will likely be small. Many of the larger shallow structures have been tested into the older formations without encouragement. Devonian shale gas awaits technical and economic incentives for the development of this resource into intermediate-sized fields. The Upper Mississippi Embayment is an unexplored province with potential for intermediate-sized structural and stratigraphic traps. The Wisconsin arch-Iowa shelf is sparsely explored because of the relatively thin stratigraphic section consisting mostly of Paleozoic rocks. However, the postulated Mid-Continent Rift Zone indicated by geophysical information may contain intermediate- to giant-sized structural traps. It has yet to be proven whether natural gas might be found in these traps. The Lincoln anticline-Ozark uplift province is a structurally high area with Precambrian rock outcrops and does not appear to have natural gas potential. The Forest City basin has been moderately drilled and explored. Potential traps may be either structural or stratigraphic with the accumulations of natural gas most likely to be of small size.

P-200, MICHIGAN BASIN

The Michigan basin geologic province includes the state of Michigan and portions of northern Indiana, northwestern Ohio, northeastern Illinois, and eastern Wisconsin. The province is bordered on the north and east by the Canadian border, on the west by the Wisconsin arch and on the south by the Kankakee and Findlay arches. The basin is an almost perfectly circular structural basin. Precambrian crystalline rocks outcrop around the northern rim of the basin. Erosion has not uncovered Precambrian rocks around the southern rim, but formations as old as Ordovician are exposed in Ohio and Indiana. In the center of the basin, Precambrian rock lies at a depth of 18,000 feet or more. The youngest widespread bedrock formations are Jurassic and Pennsylvanian sedimentary rocks which occur toward the center of the basin. These bedrock formations are overlain by up to 1,200 feet of glacial deposits. The sedimentary rocks within the basin consist predominantly of Paleozoic carbonate rocks with some sandstones. Production of both natural gas and oil has been established from many fields within the basin.

Since 1929, approximately 42,000 wells have been drilled within the Michigan Basin, the majority of which have tested relatively shallow formations (less than 6,000 feet) along anticlinal trends within the central basin area. Since 1980, there have been 248 wells drilled deeper than 8,000 feet with 134 holes drilled below 10,000 feet.

The Middle Ordovician St. Peter Sandstone is a relatively new exploration target which has yielded significant new deep gas reserves in the central basin area. Only 1,583 wells have tested this horizon with the majority of these drilled in the shallow, less prospective southern flank of the basin. Approximately 20-25 percent of the known shallow structures in the central basin area have been tested through the Lower Ordovician.

Generally, the sedimentary rocks shallower than 6,000 feet are in a mature stage of exploration and offer little potential for substantial new gas discoveries. Sedimentary rocks deeper than 6,000 feet offer the greatest potential for new gas discoveries.

The resources included in the Probable category will be found in field development and extensions. Possible gas resources are expected to be found in fields ranging in size from 2-100 Bcf with most of them estimated to be in the 5-20 Bcf range. The resources classified as Speculative are expected to be found in fields ranging from 1-50 Bcf with the most likely size between 5-25 Bcf.

A portion of the Speculative potential for the Michigan basin lies beneath waters of the Great Lakes (maximum: 550 Bcf; most likely: 250 Bcf; minimum: 50 Bcf). These areas are currently withdrawn from exploration and development. The estimated potential for these offshore areas is included within the estimate for the total Michigan basin.

Reservoir rocks. Currently productive and potential reservoir rocks range from the Middle Ordovician (St. Peter) sandstones to the Mississippian (Berea, "Stray" and Marshall sandstones). Dolomites and sandstones are the principal potential reservoir rocks, and all potential reservoirs from the early Ordovician to the Carboniferous are already productive of gas or oil. Central basin formations of Silurian, early Ordovician and Cambrian age, including sandstones and dolomites, are potential reservoirs.

Traps. Reefs are common traps in Silurian (Niagaran) and in Devonian (Traverse) strata. Porosity and permeability variations also form traps in Ordovician, Devonian and Mississippian-Pennsylvanian lithologies. Anticlines and faulted anticlines form traps in Ordovician, Silurian, Devonian and Mississippian-Pennsylvanian beds. Secondarily dolomitized fracture trends accumulate major oil and gas reserves in middle Ordovician carbonates.

Potential source rocks. Potential source rocks for natural gas are predominantly Devonian shales and carbonate rocks (Antrim and Bell Shales, Traverse Group carbonates). The Salina A1 Carbonate is the most likely source for Silurian reef gas accumulations. The Upper-Middle Ordovician Glenwood Shale is considered the source for upper St. Peter reservoirs and the

shales within the Prairie du Chien are a possible source for the deeper St. Peter reservoirs. The Middle Ordovician Trenton-Black River carbonates are also considered a potential hydrocarbon source.

Producing trends. The Niagaran reef trend, the Albion-Scipio type fracture trends and the St. Peter sands are the principal gas producing areas to date. Production generally is from less than 8,000 feet. Gas occurs in the Middle Ordovician St. Peter at depths as great as 11,630 feet primarily along anticlinal trends in the central basin area.

P-210, CINCINNATI ARCH

The Cincinnati arch is a wide area of uplift which stretches from Ohio and Indiana southward through Kentucky and Tennessee into northernmost Alabama. The northern portion of the arch splits east and west into two branches which wrap around the southern end of the Michigan basin. The western branch is known as the Kankakee arch and the eastern as the Findlay arch. The southern end of the Cincinnati arch is somewhat separated from the remainder by an area in southern Kentucky, known as the Cumberland saddle, in which the axis of the arch plunges downward. The southernmost portion, south of the Cumberland saddle, is known as the Nashville dome. The Appalachian basin lies to the east and the Illinois basin to the west. The Cincinnati arch complex began its major upwarping in the Silurian Period. The crest is wide and the dips are exceptionally gentle. Most of the accumulations of gas and oil in western Ohio occur along the structurally highest part of the Findlay arch. Sedimentary rocks in the province range in age from Cambrian to Pennsylvanian and are relatively thin. Natural gas and oil production have been established in all the states of this province.

The great Lima-Indiana field of eastern Indiana and western Ohio was discovered in 1884. Maximum production from this field was reached in 1896.

Reservoir rocks. Productive and potential reservoir rocks for gas and oil range in age from Cambro-Ordovician to Mississippian. The most common reservoir rocks are limestones and dolomites. Apart from

P-200, MICHIGAN BASIN
Generalized Stratigraphic Section

AGE	FORMATION
Paleozoic	
Pennsylvanian	Grand River Fm. Saginaw Fm.
Mississippian	Grand Rapids Group- Michigan Fm. *Marshall Ss. *Coldwater Sh. *Ellsworth Sh.
Devonian	Sunbury Sh. *Berea Ss. Bedford Sh. *Antrim Sh. *Traverse Group Bell Sh. *Rogers City-Dundee Ls. Detroit River Group *Lucas Fm. Amherstburg Fm. Sylvania Ss. Bois Blanc Fm.
Silurian	Garden Island Fm. Bass Islands Dolo. Salina Group **A-E Units *Niagara Group *Clinton Group Cataract Group Cabot Head Sh. Manitoulin Dolo. Unfifferentiated Cincinnatian rocks Utica Sh. *Trenton Group *Black River Group Glenwood Sh.
Cambrian	*St. Peter Ss. *Prairie du Chien Group #Trempealeau Fm. Munising Fm. Franconia Fm. Galesville Ss. #Eau Claire Fm.
Precambrian	Mount Simon Ss. Jacobsville Ss.

* Currently producing ** Some units productive
Potentially productive

the Devonian Salina-Niagaran Groups, all prospective reservoirs are already productive. The western Ohio fields on the Findlay arch produce chiefly from the Trenton Formation of Ordovician age. Trenton and Black River Limestones (Ordovician) are the principal reservoir formations in northern and eastern Indiana. Silurian carbonate rocks are the most prolific reservoirs in Kentucky, including the Lego (Louisville), Laurel and Brassfield, but production has also been found in Middle Devonian limestones and sandstones, the Ordovician Trenton-Black River-Chazy and the Cambro-Ordovician. Tennessee fields produce from Mississippian, Silurian and Ordovician limestones.

Traps. Production in the Trenton-Black River Limestones is due to irregularly distributed dolomitization porosity enlarged by weathering before subsequent submergence. The principal traps in the Silurian reservoirs of Kentucky occur where porosity zones have been truncated by erosion and sealed by the deposition of the Devonian New Albany (Chattanooga) Shale immediately above the unconformity. Some Ordovician production is from fracture porosity, and there are some reef limestones encased in younger shales. Accumulation in Tennessee appears to be due to varying permeability within the reservoir rocks and to the presence of small folds.

Source rocks. Late Cambrian, Mississippian, and Pennsylvanian shales are considered to be fair to good sources for natural gas.

P-220, ILLINOIS BASIN

This province includes most of the state of Illinois and portions of western Kentucky and Indiana. The province is bounded on the north by the Kankakee arch, on the east by the Cincinnati arch complex and on the south by the Pascola arch. To the west, the basin is bounded by the Mississippi River arch-Lincoln anticline. The province is predominantly an oil-producing province, but some natural gas is produced in small quantities. Sedimentary rocks consist primarily of Paleozoic dolomites, limestones, shales, and sandstones which reach a thickness of at least 20,000 feet in the deepest part of the basin.

P-210, CINCINNATI ARCH
Generalized Stratigraphic Section

AGE	FORMATION		
	Indiana	Ohio	Kentucky
Cenozoic			
Pleistocene	Martinsville Fm. Prospect-Wedron Fm. Jessup-Atherton Fm.	tills & outwash	fluvial & outwash with some till
Paleozoic			
Pennsylvanian			Caseyville Fm. *Pennington Fm. Bangor Ls. Hartsell Fm. Monteagle Ls. Kidder-Girkin Mbr. *Ste. Genevieve Ls.
Mississippian			*St. Louis Ls. Salem Ls. Harrodsburg Ls.
	St. Louis Ls. Salem Ls. Harrodsburg Ls. Ramp Creek Fm. Borden Group Rockford Ls.	Cuyahoga Fm.	Borden-New Providence Fm. Rockford Ls.
Miss.-Devonian	New Albany Sh. Ellsworth Sh.	Sunbury Sh. *Berea Ss. Ohio Sh.	*Berea Ss. Ohio Sh.
Devonian	Antrim Fm. Muscatatuck Group *N. Vernon-Traverse Fm. Jeffersonville Fm.	Traverse Fm. Detroit River Fm. Bass Island Dolo.	*Corniferous Group Boyle Dolo.-Beechwood Fm. Jeffersonville Ls. Bayley Ls.
Silurian	Salina Group Wabash Fm. Pleasant Mills Fm. Salamonie Dolo. Laurel Mbr.	A-G Units Lockport Dolo.Group Tymochtee Dolo. Guelph-Goat Is. Dolo. Gasport Dolo.	*Louisville-Brownsport Fm. *Laurel Dolo.
	Osgood-Stroh Mbr. Sexton Creek Ls. Maquoketa Group *Trenton Ls. *Black River Group Platin Fm. Pecatonica Fm.	Rochester Sh. Cataract Group Undiff. Cincinnati rks. *Trenton-Lexington Ls. *Black River Ls.	Osgood Fm. *Brassfield Dolo. Cumberland-Drakes Fm. Lexington Ls. High Bridge Group Tyrone and - -Camp Nelson Ls.
Ordovician	Ancell Gp-St. Peter Ss. *Knox Dolo.	Wells Creek Fm. *Knox Dolo.	Wells Creek Dolo. Knox Group *Beekmantown Dolo. *Cooper Ridge Dolo.
Camb.-Ordo.			
Cambrian	Franconia Fm. Ironton Ss. Galesville Ss. Eau Claire Fm. Mount Simon Ss.	Eau Claire Fm. Mount Simon Ss.	Conasauga Fm. *Rome Fm.

*Currently producing

Reservoir rocks. Reservoirs for oil and gas exist in rocks of Ordovician to Pennsylvanian age. Lithologies vary from sandstone to limestone and dolomite. Apart from the Devonian New Albany Shale, all potential reservoir rocks are already productive of oil or gas. The principal production comes from Mississippian Chesterian sandstones, Ste. Genevieve, St. Louis and Salem Limestones, Pennsylvanian sandstones, and the Ordovician Trenton-Galena Limestone.

Traps. Although there are many examples of stratigraphic traps in which there is no structural closure and the up-dip edge of the reservoir is sealed by porosity attenuation, some of the most prolific production in the basin has come from reservoirs in which there is continuous porosity and permeability across the tops of anticlines and other structural highs. Relatively minor fractions of the basin's production is associated with faults and Silurian reefs.

Source rocks. Among the good source rocks for oil and gas are the Devonian-Mississippian New Albany shale, the upper Ordovician Maqueoketa shale and the Middle Ordovician Guttentub Limestone. Potential source rocks of Cambrian to Pennsylvanian age range from immature to very mature.

Coalbed methane. Estimated in-place resources of methane in coals of the Illinois basin are 5.2 to 21.1 Tcf. Recoverable resources are estimated at 0.4 Tcf. There is no recorded commercial production of coalbed methane from this province to date.

P-230, UPPER MISSISSIPPI EMBAYMENT

This province includes portions of northeastern Kansas, southeastern Missouri, northern Mississippi, western Kentucky and western Tennessee. The province is bounded on the south by the Black Warrior and Desha basins, on the west by the Arkoma basin, on the north by the Illinois basin and on the east by the Nashville Dome. No gas or oil production has been established in this region to date. Sedimentary rocks in this province are predominantly Paleozoic sandstones and carbonate rocks which may reach a maximum thickness of 20,000 feet.

P-240, WISCONSIN ARCH, SIOUX UPLIFT AND IOWA SHELF

This province includes the states of Minnesota and Wisconsin and portions of South Dakota, Iowa and northern Illinois. The province is bounded on the north by the Canadian border, on the east by the Michigan basin, on the south by the Forest City basin, and on the west by the Siouxana and Chadron arches and the Williston basin. No production of natural gas or oil has been established to date. Sedimentary rocks are predominantly Paleozoic carbonate rocks and sandstones and probably are generally less than 15,000 feet thick. Recent exploration interest has been focused on the Mid-Continent Rift Zone which traverses the province from northeast to southwest. It is postulated that considerable thicknesses of sedimentary rocks were deposited along this tectonic trend in elongate fault-block basins which may contain potential reservoir and source rocks. The faulting which is associated with the rift zone may have originated in Precambrian time and continued to affect Paleozoic sedimentation as well.

P-250, LINCOLN ANTICLINE AND OZARK UPLIFT

This province includes portions of Missouri and northern Arkansas. It is bounded on the east by the Lincoln anticline/Mississippi River arch, on the south by the Arkoma basin and on the northwest by the Forest City basin. In total, it encompasses an area of more than 53,000 square miles. No production of natural gas or oil has been established. Sedimentary rocks of Paleozoic age predominate. In most places, the section of sedimentary rocks is thin and basement rocks of Precambrian age are not deeply buried.

P-220, ILLINOIS BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	West	East
Cenozoic		
Quaternary	Peoria Loess Equality-Henry Fm. Glasford Fm. Banner Fm. various gravels	Martinsville Fm. Prospect-Wedron Fm. Jessup-Glasford Fm. Banner Fm. various gravels
Tertiary		
Mesozoic		
Cretaceous		
Upper	Baylis-Tuscaloosa Fm.	
Paleozoic		
Pennsylvanian	McLeansboro Group *Mattoon Fm. Bond Fm. *Modesto Fm. *Carbondale Fm. Danville Coal Mbr. Brereton Limestone Mbr. various coal mbrs. *Spoon Fm. Browning-Isabel Mbrs. Greenbush Coal Mbr. various coals & limestones McCormick Group *Abbott Fm. *Caseyville Fm.	McLeansboro Group *Mattoon Fm. Bond Fm. Patoka Fm. Shelburn Fm. *Carbondale Group Danville Coal Mbr. Providence Ls. Mbr. various coal mbrs. Staunton Fm. Seelyville Coal Mbr. various coals & limestones
Mississippian	various limes, sand and shale *Tar Springs Ss. Okaw Group Glen Dean Ls. *Hardinsburg Ss. *Haney Ls. *Fraileys Sh. *Beech Creek Ls. Paint Creek-W. Baden Gp. *Cypress Ss. Cedar Bluff Group *Aux Vases Ss. *Ste. Genevieve Ls. *St. Louis Ls. *Salem Ls. *Ullin Ls. *Warsaw-Ft. Payne Fm. Keokuk-Burlington Ls. Chouteau Ls.	Brazil Fm. *Mansfield Fm. Buffalo Wallow Group Tar Springs Ss. Stephensport Group Glen Dean Ls. *Hardinsburg Ss. Haney Ls. *Big Clifty Fm. Beech Creek Ls. West Baden Group *Cypress-Elwren Ss. *Paoli Ls. *Aux Vases Fm. *Ste. Genevieve Ls. *St. Louis Ls. *Salem Ls. *Harrodsburg Ls. *Muldraugh Fm. *Borden Group Rockford Ls.

*Currently producing

P-220, ILLINOIS BASIN (Continued)
Generalized Stratigraphic Section

AGE	FORMATION	
	West	East
Paleozoic		
Miss.-Devonian	#New Albany Group	*New Albany Sh.
Devonian	*Cedar Valley-Lingle Fm.	*N. Vernon Ls.
	*Wapsipinicon-Grand Tower Fm.	*Jeffersonville Ls.
	*Clear Creek Chert	Clear Creek Chert
	Backbone Ls.	*Backbone Ls.
Silurian	*Bailey Ls.	Bailey-Liston Creek Ls.
	*Racine-Moccasin Spgs. Fm.	Mississinewa Sh.
	Joliet-St. Clair Fm.	St. Clair-Salamonie Dolo.
	*Kankakee-Sexton Ck. Ls.	Sexton Ck-Brassfield Ls.
	*Edgewood Ls.	
Ordovician	Maquoketa Group	#Maquoketa Group
	*Galena Group	*Trenton-Lexington Ls.
	Platteville Group	Black River Group
	Pecatonica Fm.	Pecatonica Fm.
	Ancell Group	Ancell Group
	Glenwood Fm.-Joachim Dolo.	Joachim Dolo.
	St. Peter Ss.-Dutchtown Ls.	St. Peter Ss.-Dutchtown Ls.
	Everton Dolo.	
	Prairie du Chien Gp.	Knox Dolo.
	Shakopee Dolo.	
	New Richmond Ss.-Oneota Dolo.	
	Gunter Ss.	
Cambrian	Eminence Fm.	Knox Dolo.
	Potosi Dolo.	
	Franconia Fm.	Franconia Fm.
	Ironton Ss.	Ironton Ss.
	Galesville-Davis Fm.	Galesville-Davis Fm.
	Eau Claire Fm.	Eau Claire Fm.
	Mt. Simon Ss.	Mt. Simon Ss.
Precambrian		

*Currently producing #Potentially productive

P-260, FOREST CITY BASIN AND CHEROKEE BASIN

This province includes an area of more than 63,000 square miles and covers portions of eastern Kansas, southeastern Nebraska, southwestern Iowa and northwestern Missouri. It is bordered on the southwest by the Nemaha uplift, on the southeast by the Ozark uplift, and on the east by the Mississippi River arch/Lincoln anticline. Currently nonassociated gas production has

been established in the Kansas portion of the Forest City basin and both oil and gas production in the Cherokee basin and the Missouri portion of the Forest City basin. Sedimentary rocks consist mainly of Paleozoic sandstones and limestones which are up to 20,000 feet thick.

Reservoir rocks. Production of natural gas and oil stems dominantly from Mississippian and Pennsylvanian sandstones and carbonate rocks. The Siluro-Devonian "Hunton" Limestone and the mid-Ordovician Viola/Simpson Limestones are productive of oil in

the Forest City basin. Potential reservoir rocks range in age from Cambrian to Pennsylvanian. Sandstones and carbonate rocks are equally important as potential reservoirs.

Traps. Stratigraphic and structural traps are small, but equally abundant, in Pennsylvanian and pre-Pennsylvanian reservoirs. Stratigraphic trap types include porosity and lithology changes, onlaps, sand-

stone lenses, channels and bars. Structural trap types include both anticlines and faulted anticlines.

Potential source rocks. The thermally immature to mature Pennsylvanian Cherokee Shale and some Mississippian shales and limestones are thought to be good potential sources for both natural gas and oil. The same is true for the Devonian-Mississippian Chattanooga Shale which is ultimately immature.

P-260, FOREST CITY AND CHEROKEE BASINS
Generalized Stratigraphic Section

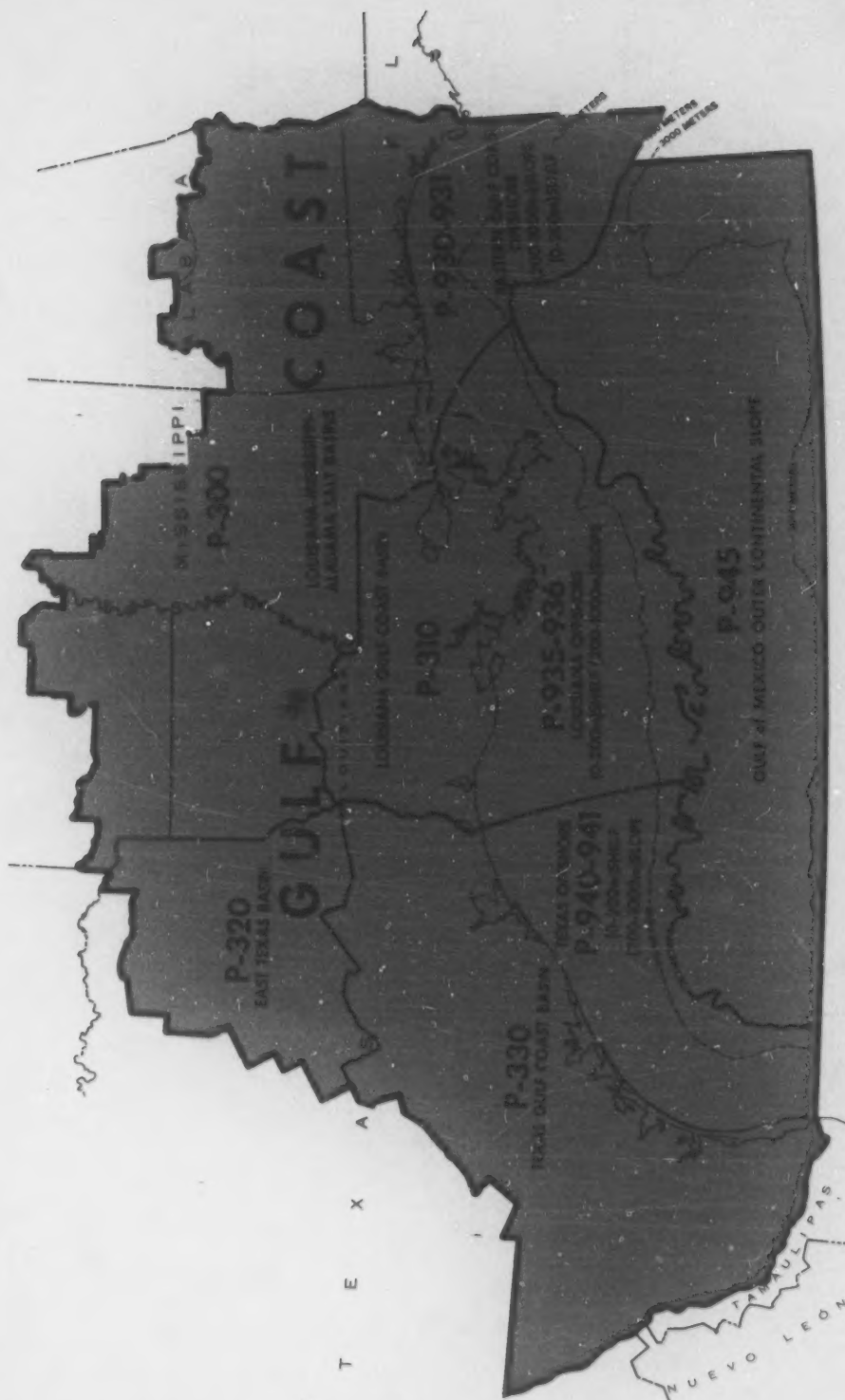
AGE	FORMATION	
	West	East
Paleozoic		
Permian	*Foraker Ls. *Admire Group Janesville Sh. Falls City Ls. Onaga Sh.	Indian Cave Ss.
Pennsylvanian	*Wabaunsee Group *Shawnee Group *Douglas Group *Lansing Group Kansas Group Pleasanton Group *Marmaton Group *Cherokee Group "Pennsylvanian basal cgl."	*Wabaunsee Group *Shawnee Group *Douglas-Pedee Groups *Lansing Group Kansas Group Pleasanton Group *Marmaton Group *Cherokee Group Riverton Fm. St. Genevieve Fm. St. Louis Fm. Salem Fm. Warsaw Fm. Keokuk-Burlington Ls. Gilmore City Fm. Chouteau Group Boice Sh. #Chattanooga Sh. Lime Creek Fm. Callaway Fm. unnamed Maquoketa Sh. Kimmswick Fm. Decorah Fm.
Miss.-Devonian	*Osagean undiff. Gilmore City Ls. Sedalia-Chouteau Fm. Boice Sh. #Chattanooga Sh.	
Devonian	Mid-Devonian undiff.	
Siluro-Devonian	*Hunton Group	
Ordovician	Maquoketa Sh. #Viola-Kimmswick undiff.	
	*Simpson Group Platteville Ls. St. Peter Ss.	Plattin Fm. St. Peter Ss.
Cambro-Ordovician	Arbuckle Group undiff.	Jefferson City Dolo. Roubidoux Fm. Gasconade Dolo. Eminence Dolo. Potosi Dolo. Derby-Doerum Dolo. Davis Fm. Bonnetterre Fm. Lamotte Ss.
Cambrian		
Precambrian	Lamotte Ss.	

*Currently producing #Potentially productive

Table 8. Estimated resources of natural gas for provinces of the North Central Area, December 1988 (billion cubic feet)

PROVINCE	ONSHORE depth	OFFSHORE water depth	PROBABLE			POSSIBLE			SPECULATIVE		
			Min.	M. likely	Max.	Min.	M. likely	Max.	Min.	M. likely	Max.
P-206, Michigan basin	0-15,000'		1,500	1,750	1,950	2,050	6,850	14,350	50	450	950
	15-30,000'								*	*	*
P-210, Cincinnati arch	0-15,000'								1,450	2,500	7,150
	15-30,000'								*	*	*
P-220, Illinois basin	0-15,000'								1,350	4,900	15,600
	15-30,000'								*	*	*
P-230, Upper Mississippi Embayment	0-15,000'								450	1,450	4,200
	15-30,000'								*	*	*
P-240, Wisconsin arch, Sioux uplift, Iowa shelf	0-15,000'								*	*	*
	15-30,000'								*	*	*
P-250, Lincoln anticline, Ozark uplift	0-15,000'								*	*	*
	15-30,000'								*	*	*
P-260, Forest City basin, Cherokee basin	0-15,000'								500	1,000	1,500
	15-30,000'								*	*	*
TOTAL, onshore	0-15,000'			1,750			6,850			10,300	
	15-30,000'			*			*			*	
TOTAL, onshore, all depths				1,750			6,850			10,300	
GRAND TOTAL FOR AREA				1,750			6,850			10,300	

*Negligible quantity of natural gas estimated.



GULF COAST AREA

All the geologic provinces of the Gulf Coast Area are potentially productive of natural gas and oil. This region is the dominant producing area of natural gas in the United States. Many of the reservoir rocks are highly porous and permeable and capable of delivering high volumes of gas. A large portion of the major natural gas pipeline system is designed to transport gas from this area to northern and eastern regions of the country. Much of the area is in a mature exploration stage, but important new fields continue to be discovered. The Gulf of Mexico continental slopes and the eastern Gulf shelf are still in the early stages of exploration.

Several changes have been made in Gulf Coast resource estimates since the last publication of the Potential Gas Committee. A new province, the Gulf of Mexico Outer Continental Slope (P-945), has been added to encompass all the area of the western Gulf of Mexico beyond the previous water depth limit of 1,000 meters to depths of approximately 3,000 meters at the United States-Mexico boundary. Recent leasing activity and exploration in this area have led the Potential Gas Committee members to include it within the limits of potentially productive territory of the United States. As of this report, only Speculative potential is reported, since commerciality of this province has yet to be established.

Changes in the estimates of potential gas resources for the remaining offshore provinces of the Gulf Coast Area primarily reflect transfers from potential resources to proved reserves as the result of continued drilling and discoveries. However, the Speculative potential was increased for the Texas Offshore Shelf and Slope (P-940 and P-941) in order to take into account recent data which have led to the recognition of additional potential traps for natural gas.

For this report, the four onshore provinces have been reevaluated in light of total natural gas reserves

proven to date and the finding rates for natural gas over the past 15 years. As a result of this reevaluation, estimates of Probable, Possible and Speculative resources have been increased significantly for the Texas Gulf Coast basin (P-330), and Probable and Possible estimates have been increased for the East Texas basin (P-320). On the other hand, poorer than anticipated wildcat success rates necessitated a marked reduction in estimates of Possible resources for the Louisiana-Mississippi-Alabama Salt Basins (P-300). As with the offshore provinces, the remaining changes largely reflect transfers from potential resources to proved reserves.

P-300, LOUISIANA-MISSISSIPPI- ALABAMA SALT BASINS

This region is bounded on the northwest by the Ouachita Mountains, and on the northeast and east by the Paleozoic Black Warrior basin and the southern extent of the Eastern Thrust Belt. North Louisiana contains three structural uplifts: the Sabine uplift, the LaSalle uplift, and the Monroe uplift. Northeast-southwest trending faults flank the east side of the Sabine uplift. Other structural elements include Jackson Dome, an igneous intrusion in central Mississippi; the Hachtigbee anticline; and the Pickens-Gilbertown-Pollard fault zone, which is an extension of the Mexia-Talco fault zone of the East Texas basin. The Hancock ridge, Wiggins uplift, Mobile graben and Conecuh arch are important features in southern Mississippi and Alabama. The region contains more than 80 salt domes and has many other salt-deformation-related features. It is a major producing province of oil, non-associated gas and associated/dissolved gas. Hydrogen sulfide and carbon dioxide often contaminate natural gas in the Smackover and Norphlet Formations.

P-300, LOUISIANA-MISSISSIPPI-ALABAMA SALT BASINS
Generalized Stratigraphic Section

AGE		FORMATION		
		Cent.-N. Louisiana	Mississippi	Alabama
Cenozoic				
	Pleistocene	Terraces-Alluvium	Terraces-Alluvium	Terraces-Alluvium
	Pliocene	Terraces	#Citronelle Fm.	Citronelle Formation
	Miocene	Fleming Fm.	#Pascagoula- -Hattiesburg Fm.	*Pensacola Clay
	Oligocene	Catahoula Fm.	Catahoula Fm.- -Chickasawhay Ls.	#Tampa Fm.- -Chickasawhay Ls.
	Eocene	Vicksburg Group Jackson Group *Claiborne Group *Wilcox Group	Vicksburg Group *Jackson Group *Claiborne Group *Wilcox Group	Jackson Group #Claiborne Group #Wilcox Group
	Paleocene	Midway Group **"Monroe Gas Rock"	#Midway Group	Midway Group
Mesozoic				
	Cretaceous			
	Upper	*Navarro Group- -"Monroe Gas Rock" *Taylor Group *Austin Group Tuscaloosa Group *Lower Tuscaloosa Fm.	*Selma Group *Eutaw-Austin Group Tuscaloosa Group *Lower Tuscaloosa Fm.	*Selma Group *Eutaw Formation Tuscaloosa Group *Lower Tuscaloosa Fm.
	Lower	*Washita Group *Fredricksburg Group *Trinity Group *Sligo Fm. *Hosston Fm. *Cotton Valley Group *Haynesville Fm. *Smackover Fm. #Norphlet Fm. Louann Salt #Werner Fm.	*Washita-Fredricks. Groups *Paluxy Fm. *Mooringsport Fm. *Rodessa Fm. *Sligo Fm. *Hosston Fm. *Cotton Valley Group Haynesville-Buckner Fm. *Smackover Fm. *Norphlet Fm. Louann Salt Werner Fm.	*Washita-Fredricks. Groups *Paluxy Fm. *Mooringsport Fm. *Rodessa Fm. *Sligo Fm. *Hosston Fm. *Cotton Valley Group Haynesville Fm. *Smackover Fm. *Norphlet Fm. Louann Salt Werner Fm.
	Jurassic			
	Triassic	#Eagle Mills Fm.	#Eagle Mills Fm.	#Eagle Mills Fm.
	Paleozoic	#undifferentiated	#undifferentiated	#undifferentiated
		* Currently producing	# Potentially productive	

The gas found in deeper drilling in older fields, along with field extensions and new pool tests, is included in the Probable resource estimates. Possible resources are estimated to be found in new fields ranging in size from 40 to 600 Bcf with an average range of 60 to 100 Bcf. Speculative resources are estimated to occur in fields of 100 Bcf to 1 Tcf with the most likely field sizes in the range of 200 to 500 Bcf.

Reservoir rocks. Production ranges in age from Tertiary to Jurassic Miocene sandstones produce gas in southern Alabama. Oil and gas are found in Eocene sandstones in Louisiana and Mississippi. Upper Cretaceous reservoirs are predominantly carbonates, however, the lower Tuscaloosa Formation produces oil from sandstones. Lower Cretaceous and Jurassic reservoirs include carbonates and sandstones. Some formations, such as the Cotton Valley and Smackover produce from both sandstones and carbonate facies. Oolitic zones form important reservoirs in the Smackover Formation. Eolian sandstones in the Norphlet Formation are the targets of recent exploration in Lower Mobile Bay, Alabama.

Traps. Trapping in the region is largely associated with salt deformation. This includes salt domes, truncations, sandstone onlap onto structures and anticlines. Fault-related traps are very important around salt domes, the Jackson dome, the east side of the Sabine uplift, and in the Pickens-Gilbertown-Pollard fault zone. Production from fault traps is frequently on the upthrown block. Lenticular sandstones are common throughout the province. Reefs occur in the Washita Group. A major regional unconformity exists between Lower Cretaceous and Upper Cretaceous rocks. Several smaller unconformities also form traps.

Source rocks. Source rocks range in age from Tertiary to Jurassic. Tertiary source rocks are the Claiborne, Wilcox and Midway Groups. Cretaceous source rocks include the Selma Group, Eutaw Formation, Tuscaloosa Group and Hosston Formation. Jurassic source rocks include the Cotton Valley Group, Smackover Formation and downdip facies of the Norphlet Formation.

Trends. Wilcox and lower Tuscaloosa sandstones produce in the southern portion of the province in Louisiana and Mississippi. The chalky carbonates of the Monroe "gas rock" are significant gas producers on the Monroe uplift. The Sligo and Hosston Formations

are important gas intervals in the North Louisiana basin. The Hosston is also important in south-central Mississippi. The Cotton Valley and Smackover Formations are prolific in southern Arkansas and northernmost Louisiana and southeast from the Jackson dome along the Pickens-Gilbertown-Pollard fault zone. To date, success in finding production from the Norphlet Formation has been widely scattered along the Smackover trend, however, a remarkable concentration of large gas fields occurs in the Norphlet at depths below 20,000 feet in Lower Mobile Bay, Alabama and adjacent federal waters.

P-310, LOUISIANA GULF COAST BASIN (ONSHORE)

The Louisiana Gulf Coast Basin is one of the major oil and gas provinces in the United States. It is the lower part of the Mississippi Embayment. Most of the province is covered by Quaternary deposits, but Tertiary rocks outcrop in the northern portion. An extremely thick clastic wedge of fluvial and deltaic sediments was deposited. Regional structure is largely the result of differential sedimentation related to salt flowage and the associated contemporaneous faulting. Salt domes are abundant and both salt and sulphur are mined.

The South Louisiana onshore basin is one of the most extensively explored areas in the United States. A large percentage of the hydrocarbons found to date above 15,000 feet have been crude oil with dissolved and associated gas caps. Some 90 percent of the significant anticlinal or fault closures above 15,000 feet have been tested by one or more wells.

Gas discoveries in recent years have found fields ranging in size from 2 to 150 Bcf with average size of some 8 Bcf. Size of future discoveries above 15,000 feet will likely average less than the 8 Bcf. Resources classified as Speculative will be found in fields varying in size from 2 to 500 Bcf with average being 30 to 50 Bcf.

Reservoir Rocks. South Louisiana produces from Tertiary through Cretaceous rocks. Tertiary reservoirs are mainly sandstones capped by shales of Miocene, Oligocene and Eocene age. Cretaceous reservoirs are

P-310, LOUISIANA GULF COAST BASIN (ONSHORE)
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Pleistocene	various
Pliocene	Citronelle Fm.
Miocene	*Fleming Fm. *"Upper Miocene" *"Middle Miocene" *"Lower Miocene"
Oligocene	*Catahoula Group *Anahuac Fm. *Frio Fm.
Eocene	*Vicksburg Group Jackson Group Claiborne Group *Cockfield Fm. Cook Mountain Fm. *Sparta Fm. Cane River Fm. Carrizo Fm.
Paleocene	*Wilcox Group
Mesozoic	Midway Group
Cretaceous	Selma Chalk
Upper	Navarro Group Taylor Group *Austin Chalk Tuscaloosa Group *Lower Tuscaloosa Fm.
Lower	#Washita undiff. #Fredricks. undiff. #Paluxy Fm. #Trinity Group Mooringsport Fm. *Rodessa Fm. Pine Island Fm. *Sligo Fm. #Hosston Fm.

*Currently producing #Potentially productive

largely oil-bearing carbonates, but significant gas is present in Tuscaloosa sands and Sligo carbonates. The thick Miocene wedge dominates South Louisiana in both oil and gas production.

Traps. The major trapping mechanisms in this province are faulted anticlines and salt domes. A high percentage of these traps are fault-related. Truncations with overlaps influence some reservoirs. Many stratigraphic traps, including updip porosity wedgeouts, occur in the Cretaceous carbonates.

Source rocks. Thick, organic-rich, Cretaceous and Tertiary shales provide ample sources for hydrocarbons in this prolific province.

Trends. Starting with the Lower Cretaceous in the northern portion of the province, the major trends parallel the coastline in bands of progressively younger sedimentary rocks in the following sequence: Lower Tuscaloosa, Wilcox, Oligocene, Lower Miocene, Middle Miocene and Upper Miocene.

P-320, EAST TEXAS BASIN

The East Texas basin, or Tyler basin, occupies northeastern Texas. It is bounded on the north and west by the Ouachita Tectonic Belt and is separated from the North Louisiana basin to the east by the Sabine uplift. The Angelina-Caldwell flexure separates it from the Texas Gulf Coast basin to the south. The East Texas basin is part of the Mississippi Embayment. Upper Cretaceous rocks outcrop in the western and northwestern portions. Progressively younger rocks outcrop to the south and east. The two most prominent structural features in the basin are the Mexia-Talco fault system, which parallels the Ouachita Tectonic Belt on the west and north margins of the basin, and the Sabine uplift to the east. The Mexia-Talco system extends eastward into the Louisiana-Mississippi-Alabama salt basin. The Mt. Enterprise fault system extends westward from the southern flank of the Sabine uplift to near the central portion of the basin. Several regional unconformities occur in this basin. There are also numerous salt domes, salt anticlines and related residual or "turtle back" structures.

The East Texas Basin is a maturely explored province. Resources included in the Probable category will be found in field extensions and infield drilling. Possible resources will likely be found in new fields ranging in size from 5 to 50 Bcf. Speculative resources probably will be found in fields from 20 to 500 Bcf.

Reservoir rocks. Production ranges in age from Jurassic to Tertiary. The only Tertiary production is from sandstones to the Wilcox and Claiborne Groups. Upper Cretaceous production is from carbonates in the Taylor and Austin Groups, and sandstones in the Eagleford and Woodbine Groups. Lower Cretaceous reservoir rocks are predominantly carbonates, but sandstones produce in the Paluxy and Travis Peak Formations. Jurassic reservoirs include sandstones and carbonates in the Cotton Valley Group and Smackover Formation. Paleozoic sandstones and carbonates are potential reservoirs in the northern and western portion of the basin.

Traps. Combination structural-stratigraphic traps are very common throughout the province and affect most of the stratigraphic intervals. Anticlines, faulted anticlines and faults are the most common structural mechanisms, particularly in the Woodbine and Smackover. High energy sand and carbonate facies, in combination with various structures, form traps in the Tertiary, Upper and Lower Cretaceous units and portions of the Jurassic. Reef facies form traps in the James Limestone. Salt domes are less important as traps in the basin. Local and regional unconformities also form traps, the most notable of which is the East Texas field.

Source rocks. The source rocks for this province are probably shales adjacent to the various reservoirs. Carbonates are possible sources in parts of the area, as are transgressive shales overlying unconformities.

Trends. Notable trends include the Mexia-Talco Fault zone and the Smackover trend which generally parallels the Mexia-Talco trend but lies farther downdip. Two Cotton Valley trends occur, one in an arcuate pattern around the western flank of the Sabine uplift, and the other along the southwestern portion of the basin. Most of the major Upper and Lower Cretaceous producing formations occur basin-wide and are not situated in trends.

P-320, EAST TEXAS BASIN Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Pliocene	Goliad Fm.
Miocene	Fleming Fm.
Oligo.-Miocene	Catahoula Fm.
	Vicksburg Fm.
Eocene	Jackson Group
	*Claiborne Group
	*Wilcox Group
Paleocene	Midway Group
Mesozoic	
Cretaceous	
Upper	Navarro Group
	*Taylor Group
	*Austin Group
	*Eagleford Group
	*Woodbine Group
Lower	*Washita Group
	*Fredricksburg Group
	*Paluxy Ss.
	*Glen Rose-Rusk Fm.
	Ferry Lake Anhydrite
	*Rodessa-Atascosa Fm.
	Bexar Sh.
	*James Ls.
	Pine Island Sh.
	*Sligo (Pettit) Fm.
	*Hosston (Travis Peak) Fm.
Jurassic	*Cotton Valley Group-Schuler Fm.
	Haynesville-Gilmer Fm.
	Buckner Fm.
	*Smackover Fm.
	Norphlet Fm.
	Louann Salt
	Werner Fm.
Triassic	Eagle Mills Fm.
Paleozoic	#undifferentiated

*Currently producing # Potentially productive

P-330, TEXAS GULF COAST BASIN (ONSHORE)

The Texas Gulf Coast basin covers 67 counties of southern and southeastern Texas. It encompasses part of the Mississippi Embayment and part of the Rio Grande Embayment. The Balcones Fault zone and Ouachita Tectonic Belt bound the province on the north and west. This is one of the major hydrocarbon regions of the United States. Much of the production comes from Tertiary reservoirs. Both associated/dissolved and non-associated gas are produced.

Resources classified as Possible are expected to be found in fields from 3 to 30 Bcf with most being in the 10 to 15 Bcf range. Speculative resources are expected to be found in fields varying from 10 to 100 Bcf with the most likely size being 20 to 40 Bcf.

Reservoir rocks. Tertiary sandstones, notably the Frio Formation, dominate production in this province. Upper Cretaceous reservoir units include sandstones and carbonates. Lower Cretaceous sedimentary rocks produce primarily from carbonates. All productive formations produce both oil and gas except the Lower Cretaceous Sligo and Glen Rose Formations which produce only gas.

Traps. Anticlines, domes, diapirs and faults are the most common trapping mechanisms in the region and affect all productive intervals. Salt diapirs are more common in the northern portion, whereas shale diapirs are more common in the southern portion. Stratigraphic traps are less common, but sandstone lenses, sandstone pinchouts across structures and updip pinchouts do exist in the region. Overpressured reservoirs exist on shallow salt domes as well as at deeper levels. Some Frio structures host in excess of 50 sandstone reservoir units. Reefs occur in the Cretaceous, producing primarily non-associated gas.

Source Rocks. All intervals from Tertiary to Lower Cretaceous contain likely source rocks. Most of these are bituminous shales, but limestone and chalks are also sources in the region.

Trends. Numerous trends exist in this province. They lie subparallel with both the Ouachita Tectonic Belt and the present day coast and overlap one another. Proceeding from west to east are: the Cretaceous trend,

the Wilcox trend, the Queen City-Yegua trend, the Vicksburg-Frio trend and the Miocene trend which extends offshore. The Cretaceous Edwards reef trend overlaps the Eocene Wilcox trend.

P-330, TEXAS GULF COAST BASIN (ONSHORE) Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Pleistocene	various sandstones
Pliocene	Goliad Formation
Miocene	*Lagarto Fm./Oakville-Fleming Fm. * "Catahoula" Fm. * Anahuac Fm. * Frio-Hackberry Fm. * Vicksburg Fm. * Jackson Group * Claiborne Group * Wilcox-Sabinetown Fm. * Midway Group
Paleocene	
Mesozoic	
Cretaceous	
Upper	*Escondido-Navarro Fm. * Olmos Fm. * Taylor Fm. * Austin Chalk Eagle Ford Fm. * Woodbine Fm. * Buda Fm. Del Rio Fm. * Georgetown Fm. * Edwards Group Glen Rose-Stuart City Fm. Pearsall Fm. * Sligo Fm. # Hosston Fm. Cotton Valley Fm. Buckner Fm. # Smackover Fm. # Norphlet Fm. Louann Salt Werner Fm. # Eagle Mills Fm.
Lower	
Paleozoic	# various shales & sandstones

* Currently producing # Potentially productive

P-930 and P-931, EASTERN GULF OFFSHORE, SHELF AND SLOPE

The Eastern Gulf Coast Shelf has excellent potential for future discoveries. The probability is high for continuation of trends offshore from Mississippi, Alabama and the Florida Panhandle. Commercial discoveries to date have been confined to the area offshore from Mobile Bay.

The resources classified as Possible are expected to be found in fields ranging from 50 to 750 Bcf with most of them being in the 100 Bcf range. Speculative resources will be found in fields ranging from 50 to 1000 Bcf with the most likely size being between 100 and 200 Bcf.

Reservoir Rocks. To date, gas reservoirs have been discovered in discontinuous sandstones within the Miocene Pensacola Clay and eolian sandstones of the Jurassic Norphlet Formation. Much of the Jurassic and Cretaceous section above the Norphlet is considered prospective. Speculative reservoirs could exist in sandstones and carbonates, including the Lower Tuscaloosa, Hosston, Cotton Valley and Smackover Formations.

Traps. Anticlines, fault closures, faulted anticlines, deep-seated salt swells and reefs are the most likely traps in this area. Porosity changes and regional unconformities may also form traps.

Source rocks. The most probable source rocks in this region are the Upper Cretaceous Tuscaloosa Group, Lower Cretaceous Gordo Formation, Jurassic Cotton Valley Formation and unrecognized downdip rocks.

P-935 and P-936, LOUISIANA OFFSHORE, SHELF AND SLOPE

This region is the most prolific offshore area of the United States. The shelf is only twenty miles wide at the end of the Mississippi delta, but widens to 130 miles near the Texas Gulf Coast boundary. The upper slope, as well as the shelf, is very productive. East-west trending fault zones extend from onshore out onto the shelf. Pressures encountered in the reservoirs may be much higher than normal.

Reservoir rocks. Reservoir rocks in this area are all sandstones. They range in age from Pleistocene through Miocene. Older units are buried to great depth and are not productive to date. Individual formation names are not applied in the offshore. Paleontological markers are the most commonly utilized means of identifying the stratigraphic units. Many of the units are debris flows and submarine fans.

Traps. Salt domes, growth faults and faulted anticlines are the most common trapping mechanisms in this province. Onlaps and truncations are very common. Porosity changes in the deeper reservoirs and lenticular sand bodies also form effective traps.

Source rocks. The source rocks are bituminous shales ranging in age from Miocene through Pleistocene.

Trends. The Miocene-Pliocene Fleming Trend extends from onshore, continuing offshore, to near the shelf-slope break. The Pleistocene trend starts near the Mississippi River mouth and extends on down the continental slope.

P-940 and P-941, TEXAS OFFSHORE, SHELF AND SLOPE

The Texas Offshore portion of the Gulf Coast is an important hydrocarbon producing province. The majority of production to date has been natural gas and most of the undrilled prospects are thought to be gas-prone. Potential in this region is excellent, but less than that for Offshore Louisiana.

To date, fewer than 5,000 wells have been drilled in the shelf area of 15 million acres and exploration on the slope is in its early stages. Resources classified as Possible are expected to be found in fields ranging in size from 15 to 400 Bcf with most of them being in the 20 to 50 Bcf range.

Reservoir rocks. Producing units for the Texas Gulf shelf and slope are sandstones which are not designated by formation names. They are simply referenced by geologic age or paleontological markers. The productive formations range in age from Oligocene to Pleistocene. Reservoirs produce from as shallow as 1,500 feet to in excess of 15,000 feet.

Since this area is farther from the Mississippi delta complex than Offshore Louisiana, there is a higher percentage of shale in the section and the sandstones are finer-grained. Strong longshore currents during the Tertiary had a destructive effect on the Texas Gulf Coast deltaic deposition with the resulting formation of an extensive barrier bar system. Quaternary deposits were influenced by sea level fluctuations with channel and turbidite environments predominant in proximity to the slope. Permeabilities and porosities vary in all age strata because of the diverse depositional environments.

Traps. Anticlines, faulted anticlines, shale diapirs, shallow and deep-seated salt intrusions and growth faults are the major trapping mechanisms. Stratigraphic traps include sandstone lenses, onlap, truncations and porosity variations.

Source rocks. Miocene shales are the probable source rocks for this province. It is hypothesized that vertical migration accounts for the hydrocarbon accumulation in the younger Plio-Pleistocene rocks.

P-945, GULF OF MEXICO OUTER CONTINENTAL SLOPE

The Gulf of Mexico Outer Continental Slope is a newly designated Potential Gas Committee province created to account for recent Gulf leasing and exploration in water depths greater than the previous reporting limit of 1000 meters. The new area extends downslope from the 1000 meter boundaries of the Texas, Louisiana and Eastern Gulf slopes to water depths in excess of 3000 meters at a line extending eastward from the United States-Mexico border.

Although some discoveries are apparent, commerciality is yet to be determined. Natural gas pipelines currently extend only slightly past the shelf-slope break, leaving many prospects 100 miles from a connection and up to 200 miles from shore. New, but foreseeable technology will be required to develop and produce discoveries. However, explorationists see Speculative potential for hydrocarbon accumulations large enough to justify development expenditures. Only Speculative resources will be reported until such time as commerciality is established.

Reservoir rocks. Cenozoic sandstones deposited in submarine channels, fans and debris flows are expected to be the principal reservoir rocks. Cretaceous carbonates are thought to be prospective by some explorationists.

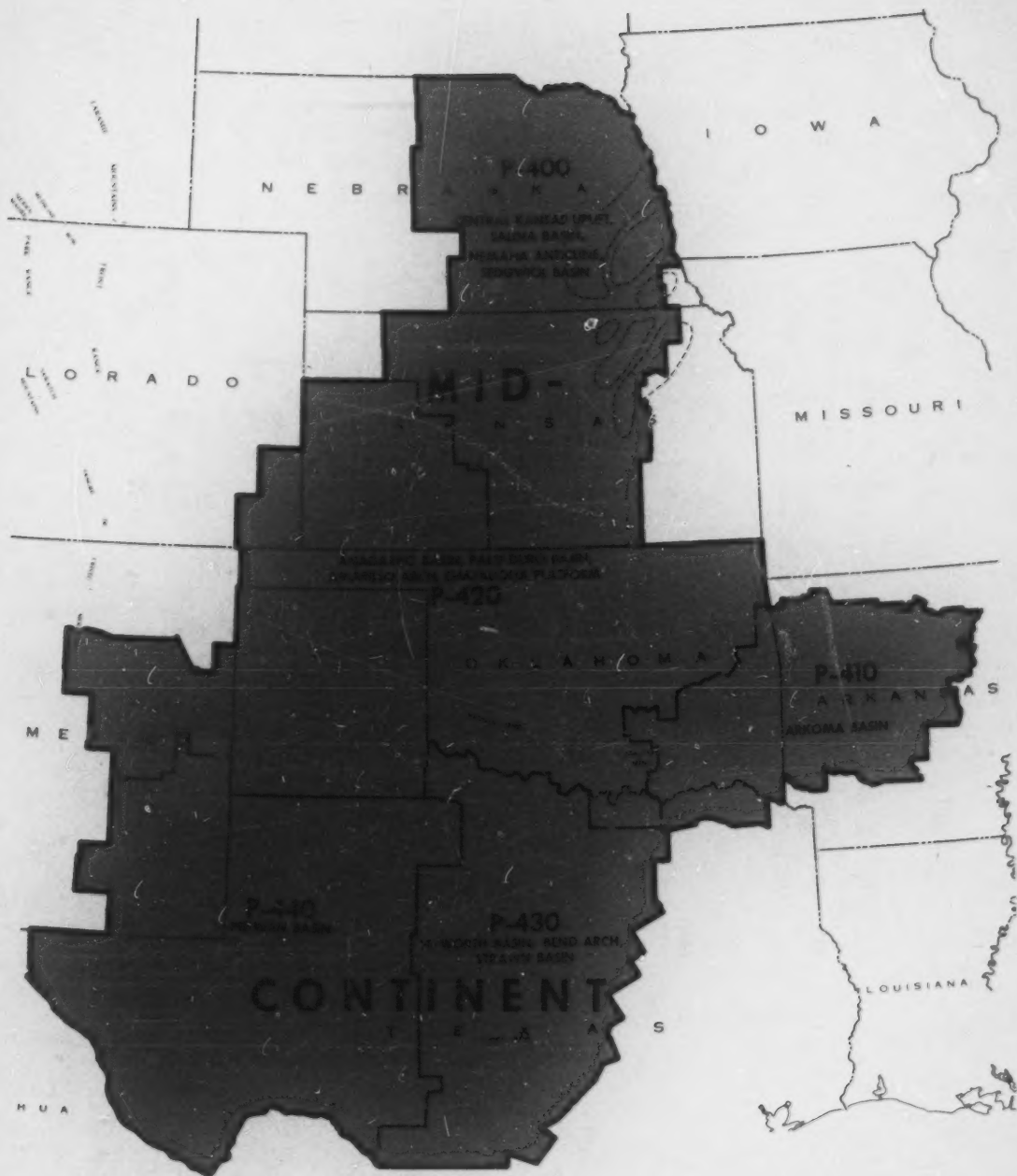
Traps. The total area encompassed by the Gulf of Mexico Outer Continental Slope is greater than the prolific shelves and upper slopes of Offshore Texas and Louisiana combined. A large area within the province is considered to be less prospective due to massive salt accumulations. The salt thins downdip forming salt tongue thrusts over younger sedimentary rocks, creating prospects in the resultant folds. Seismic data indicates trap types and trends occurring along the upper slope extend into portions of this province. Salt domes and ridges, fault closures and faulted anticlines are expected to be the principal traps. Stratigraphic factors such as sand pinchouts should also play a significant role in trap formation. Toe thrusts at the basinward extremity of growth faults form unique faulted-anticlines.

Source rocks. The source rocks are still disputed, but are thought to be principally Cretaceous shales.

Table 9. Estimated resources of natural gas for provinces of the Gulf Coast Area, December 1988 (billion cubic feet)

PROVINCE	ONSHORE depth	OFFSHORE water depth	PROBABLE		POSSIBLE		SPECULATIVE	
			Min.	M. likely	Max.	Min.	M. likely	Max.
P-300, Louisiana-Mississippi-Alabama salt basins	0-15,000'		3,200	4,550	6,650	1,800	3,650	6,100
	15-30,000'		450	1,150	1,600	2,800	5,850	9,800
P-310, Louisiana Gulf Coast basin (onshore)	0-15,000'		2,000	2,900	3,400	350	2,600	2,550
	15-30,000'		2,800	3,950	4,750	2,000	6,900	9,000
P-320, East Texas basin	0-15,000'		750	1,400	2,050	650	2,000	3,550
	15-30,000'		50	160	150	50	200	350
P-330, Texas Gulf Coast basin (onshore)	0-15,000'		600	3,200	4,700	3,400	8,700	9,300
	15-30,000'		4,100	5,500	7,050	5,150	6,600	9,250
P-930, Eastern Gulf shelf		0-200 m	2,900	4,100	5,400	1,100	5,700	20,100
P-931, Eastern Gulf slope		200-1,000 m	*	*	*	100	2,000	4,800
P-935, Louisiana shelf		0-200 m	9,700	16,300	18,500	4,200	16,200	27,800
P-936, Louisiana slope		200-1,000 m	400	1,400	2,500	3,700	12,700	22,400
P-940, Texas shelf		0-200 m	2,300	4,600	6,600	6,150	14,200	20,800
P-941, Texas slope		200-1,000 m	50	100	150	2,200	4,400	7,400
P-945, Gulf of Mexico Outer Continental Slope		>1,000 m	*	*	*	*	*	*
TOTAL, onshore	0-15,000'			12,050			16,350	
TOTAL, onshore	15-30,000'			10,700			19,550	
TOTAL, onshore, all depths				22,750			35,900	
TOTAL, offshore		0-200 m		25,000			36,100	
TOTAL, offshore		200-1,000m		1,500			19,100	
TOTAL, offshore		>1,000 m		*			*	
TOTAL, offshore, all depths				26,500			55,200	
GRAND TOTAL FOR AREA				49,250			91,100	
							3,450	
							12,550	
							16,000	
							7,800	
							9,400	
							30,000	
							47,200	
							63,200	

*Negligible quantity of natural gas estimated.



MID-CONTINENT AREA

The Mid-Continent Area is, next to the Gulf Coast Area, the most important area of current natural gas production in the country. The Area includes the Permian basin, the Anadarko basin and the extensive Hugoton-Panhandle area, all of which are important gas-producing areas and have great potential for natural gas exploration and development. Additionally, the Arkoma basin and the Fort Worth basin-Bend Arch-Strawn basin provinces are believed to have significant gas potential.

Almost all the provinces of the Mid-Continent Area are in a mature stage of exploration. It is expected that most future fields to be discovered will fall into small or intermediate size categories. The two exceptions to this generalization are the deeper portions of the Anadarko basin and portions of the Arkoma basin where extensive exploration has not yet occurred.

Reevaluation of the resource potential for the Mid-Continent Area has resulted in a downward revision in one province and the inclusion of a deep resource potential for the first time in another province. Based on disappointing results of exploration and poor production performance of some wells completed in the deep portion of the basin, the estimate of potential resources for the province (P-420) which includes the Anadarko basin has been revised downward for the depths below 15,000 feet. New discoveries of deep Arbuckle Formation gas in the Arkoma Basin (Province P-410) has resulted in the new allocation of potential resources to the deep portion of the Basin.

P-400, CENTRAL KANSAS UPLIFT, SALINA BASIN, NEMAHA ANTICLINE AND SEDGWICK BASIN

This province covers eastern Nebraska and central Kansas. Paleozoic rocks outcrop in much of the region. Lower Cretaceous rocks cover part of the western portion and Cenozoic rocks mantle parts of Nebraska. It is primarily an oil province, but both non-associated and associated/dissolved gas are produced. Most of the production in this province is along the Central Kansas uplift. The Salina basin is the least explored portion of the region. (Production is shallow—not more than 5,000 feet deep.)

Reservoir rocks. Producing horizons range in age from Cambrian to Cretaceous. Carbonate rocks of the Cambrian-Ordovician Arbuckle Group contain the major oil reservoirs in the region. Most of the gas, however, is recovered from upper Paleozoic units. Pennsylvanian-age rocks include the Lansing Kansas City and the Cherokee Group. Permian-age rocks include the Chase, Council Grove and Admire Groups.

Traps. Anticlines, faulted anticlines and domes form traps for all intervals throughout the province. Unconformity truncations affect Pennsylvanian and older units. In the Arbuckle Group, buried topographic relief provides a trapping mechanism. Traps are formed in lower Pennsylvanian units by onlap onto older structures. Variations in porosity affect both carbonate and sandstone units. Sandstones take the form of channel complexes, bars, and sheet sands.

P-400, CENTRAL KANSAS UPLIFT, SALINA BASIN, NEMAHA ANTICLINE
AND SEDGWICK BASIN
Generalized Stratigraphic Section

AGE		FORMATION
Cenozoic		
	Miocene	Ogalalla Fm.
Mesozoic		
	Cretaceous	
	Upper	*Niobrara-Ft. Hayes Ls. #Carlile Shale Greenhorn Ls. Graneros Sh. #Dakota Group
Paleozoic		
	Permian	Various Leonardian Wolfcampian
		Nippewalla Group Sumner Group *Chase Group *Council Grove Group *Admire Group
	Carboniferous	
	Pennsylvanian	
	Virgilian	*Wabaunsee Group *Shawnee Group *Douglas Group
		*Lansing Group *Kansas City Group *Pleasanton Group
	Missourian	*Marmaton Group *Cherokee Group
		Pennsylvanian Basal Cgl.
	Atokan	
	Chesterian	
	Morrowan	
	Mississippian	
	Meramecian	Meramecian undifferentiated
	Osagean	Keokuk Ls. Burlington Ls. Fern Glen Ls. Gilmore City Ls. Sedalia Dolo.
		#Chattanooga Sh. Middle Devonian undifferentiated
	Kinderhookian	Hunton Group Maquoketa Sh. Viola-Kimmswick Ls. Platteville Ls.
	Devonian	Various
	Silurian	Various
	Ordovician	Various
		*St. Peter Ss. *Arbuckle Group Bonneterre Dolo. *Lamotte Ss.
	Cambrian	Various

* Currently producing # Potentially productive

Potential source rocks. The province is dominated by carbonate rocks and shales which form the source rocks of the area. Most of these are mature, though some of the younger units are immature. All of the Pennsylvanian shales and some of the limestones are considered source rocks. Other known source rocks are the Mississippian Chattanooga Shale, and the Ordovician Maquoketa Shale.

P-410, ARKOMA BASIN

This province covers southeastern Oklahoma, western and central Arkansas. It is primarily a gas-producing province. The Oklahoma portion of the province was formerly known as the McAlester coal basin. The Arkoma basin is bounded on the north by the Ozark uplift, on the northwest by the Central Oklahoma platform and Seminole arch, on the west by the Arbuckle Mountains, on the south by the Ouachita Mountains, and on the east by the Mississippi Embayment. It is a Paleozoic basin containing more than 19,000 feet of Pennsylvanian and older rocks.

Most of this province has been explored, but there are some areas which are complex structurally and which have not yet been explored extensively. These areas lie in the southern portion of the province. The southeastern portion of the province in Oklahoma is largely untested. The Possible and Speculative estimates for the Arkoma basin include pre-Pennsylvanian potential as a result of the recent and significant deep Arbuckle Formation discovery in Wiburton field in Latimer County, Oklahoma. ARCO Oil and Gas Company has been most active with eight wells drilling or completed. This discovery has resulted in the assignment of potential resources for the first time to the deep Arkoma Basin.

Reservoir rocks. Most of the reservoirs are Des Moinesian to Morrowan. Lenticular sandstones of the Atokan Series are the major producers. Both sandstones and limestones of the Morrowan Series form reservoirs in the region. Older units (Ordovician-Silurian) produce oil and gas from sandstone and carbonate reservoirs. Some reservoirs are as shallow as 400 feet.

Traps. Anticlines and faulted anticlines form traps for all intervals. Anticlines in the province are generally large; some are up to 40 miles long and 12 miles wide with up to 3,000 feet of closure. Facies changes associated with channel sands and deltaic complexes are the dominant traps in Des Moinesian and Atokan rocks.

Potential source rocks. All stratigraphic intervals (Ordovician-Permian) provide mature source rocks for the province. Most of these are marine shales, but limestones are sources for some reservoirs.

P-420, ANADARKO BASIN, PALO DURO BASIN, AMARILLO ARCH AND CHATAUQUA PLATFORM

This is one of the major gas-producing provinces of the United States. Much of the gas is non-associated, but large quantities of oil and associated/dissolved gas are also produced. Non-associated gas is the main product in the western portion. Oil and associated/dissolved gas are the major constituents in the central and eastern portions of the region. There is very little production in the Palo Duro basin or Wichita Mountains, but the Palo Duro basin has potential for future discoveries.

The Anadarko basin is a northwest-southeast-trending depositional and structural basin. It is bounded on the north by the Cambridge arch-Central Kansas uplift, on the northeast by the Nemaha uplift, on the east by the Arbuckle Mountains, on the south by the Wichita Mountains and Amarillo uplift, on the west by the Cimarron uplift, and on the northwest by the Las Animas arch. The Anadarko basin is highly asymmetrical with the steep side next to the Wichita Mountains. The deeper portion of the Anadarko basin may contain over 40,000 feet of sedimentary rocks. The northwestern end of the basin is called the Hugoton Embayment. The Hugoton-Panhandle field complex covers all or parts of 19 counties in Texas, Oklahoma, Kansas, and Colorado. In the Hugoton area, there are between 2,000 and 7,000 feet of sedimentary rocks.

P-410, ARKOMA BASIN
Generalized Stratigraphic Section

FORMATION

AGE		LEHIGH-MCALLESTER BASIN PORTION	ARKANSAS BASIN PORTION
Paleozoic			
Permian	Wolfcampian	*Pontotoc Group	
Carboniferous	Virgilian	Ada Fm.	
	Missourian	Vamoosa Fm.	
Pennsylvanian		Hilltop Fm.	
		Belle City Ls.	
		Francis Fm.	
		Seminole Fm.	
	Des Moinesian	Holdenville Fm.	
		Wewoka Fm.	
		Wetumka Sh.	
		Calvin Ss.	
		Senora Fm.	
		*Boggy Fm.	*Boggy Fm.
		*Savanna Fm.	*Savanna Fm.
		*McAlester Fm.	*McAlester Fm.
		*Hartshorne Fm.	*Hartshorne Fm.
	Atokan	*Atoka Fm.	*Atoka Fm.
	Morrowan	*Wapanucka Fm.	*Bloyd Fm.
		*Union Valley Fm.	*Hale Fm.
Mississippian	Various	Caney Sh.	Caney Equivalent Fms.
Devonian	Various	Woodford Sh.	Chattanooga Sh.
			Sylamore Ss.
			Clifty Fm.
			Penters Chert
		Frisco Fm.	
		Haragan-Bois d'Arc Fm.	
Silurian	Various	*Henryhouse Fm.	*Lafferty Ls.
		Clarita-Quarry Mt. Fm.	St. Clair Ls.
		Cochrane Fm.	Brassfield Ls.
Ordovician	Various	Keel Fm.	Pettit Oolite
		Sylvan Sh.	Cason Sh.
		*Viola Group	Fernvale Ls.
			Kinmswick Ls.
		Simpson Group	Plattin Ls.
		Fite Fm.	Joachim Dolo.
		*Tyner Fm.	*Saint Peter Ss.
		*Bürgen Ss.	*Everton Fm.
		*Arbuckle Group	*Arbuckle Equivalents
Cambrian	Canadian	*Arbuckle Group	
	Trempealeauan-Franconian	Timbered Hills Group	Elvins Group
			Bonneterre Dolo.
			Lamotte Ss.

* Currently producing

All rocks which overlie the Ordovician in the shallower portions of the Anadarko basin are considered to be mature exploration targets and it is expected that future new field discoveries would occur in comparatively small stratigraphic traps. Ordovician exploration at depths of 10,000 to 15,000 feet is relatively immature overall; most large structures have been drilled, but many smaller structures are untested. It is expected that Ordovician rocks at depths of 10,000 to 15,000 feet may yield small and intermediate-sized fields in the future. The rocks below 15,000 feet in the Anadarko basin are still being explored. Both the Morrowan clastic rocks and the older pre-Mississippian carbonate rocks below 15,000 feet in the Anadarko basin may contain undiscovered fields with natural gas accumulations of over 40 billion cubic feet.

The deep Anadarko Basin has for the past two decades held the lure of vast untapped potential resources. After countless dry holes and disappointing results on producing completions, it has become apparent that the Basin has failed to live up to the expectations of the industry. The committee has concluded that a substantial adjustment for the deep Anadarko Basin would be appropriate. The year-end 1988 report reflects a downward revision of 58 Tcf as compared to the 1986 report for the Most Likely category.

Reservoir rocks. Producing formations range in age from Cambrian to Permian. The major reservoirs are mostly the Permian Leonardian and Wolfcampian Series rocks. Sandstones, conglomerates, limestones, and dolomites are all present in these Series. Wolfcampian carbonates of the Chase, Council Grove, and Admire Groups are the major reservoirs in the Hugoton field. Other important reservoirs in western Oklahoma and the Panhandle region include the Silurian-Hunton and the Mississippian-Chester. In central Oklahoma, the Atokan and Morrowan Series contain important sandstone and limestone reservoirs. Other reservoirs include the Viola Limestone, Simpson Sandstone and the Cambro-Ordovician Arbuckle Group.

Traps. In most of the province, anticlines and faulted anticlines are important trapping mechanisms for Permian and older rocks. In the Palo Duro basin, anticlines affect all productive intervals. Morrow sandstones consist of channel sandstones, delta complexes and littoral sand packages. Variations of permeability and updip pinchouts of permeability form common traps. In the Arbuckle, some units have vuggy

porosity development within tighter matrix rocks. Unconformities truncate some reservoirs. Evaporites form seals for part of the Amarillo uplift. The potential for hydrodynamic traps is evidenced by tilting of oil/water and gas/oil contacts in some fields.

Potential source rocks. Source rocks are good to excellent in this province. They range from immature to over-mature depending on depth of burial. Probable source rocks include all Carboniferous shales and limestones. Another likely source rock is the Devonian Woodford Shale.

P-430, FORT WORTH BASIN, BEND ARCH AND STRAWN BASIN

This province covers the central portion of Texas. It is bounded on the east by the Ouachita tectonic belt and on the south by the Balcones fault zone. It is primarily a Paleozoic province and Paleozoic rocks outcrop at the surface in the northern portion of the province. Lower Cretaceous rocks cover the Paleozoic sedimentary rocks in the southern portion of the province. The province contains no giant fields. Exploration and development costs are low in the region due to shallow production (depths of 1,300 to 6,000 feet). This makes it an attractive drilling area. Both oil and gas are produced in this province and the gas occurs as both associated/dissolved and non-associated gas.

Reservoir rocks. Reservoir rocks range in age from Cambrian to Permian. Permian reservoirs include both sandstones and limestones of the Wolfcampian and Leonardian series. Limestone, sandstone and conglomeratic rocks form reservoirs in Pennsylvanian age units. Productive carboniferous units include the Canyon, Strawn, and Atokan Series. Mississippian reservoirs are limestones of the Barnett and Chappell Formations. Ordovician reservoirs are the Viola, Simpson, and Ellenburger Formations.

P-420, ANADARKO BASIN, PALO DURO BASIN, AMARILLO ARCH
AND CHATAUQUA PLATFORM
Generalized Stratigraphic Section

AGE		TEXAS-OKLA. PANHANDLE	CENT.-WEST OKLAHOMA
Cenozoic			
Pliocene		Ogalalla Fm.	Ogalalla Fm.
Mesozoic			
Cretaceous			
Paleozoic			
Permian	Ochoan	Doxey Fm.	Quartermaster Group
	Ochoan-Guadalupian	Cloud Chief Fm.	Cloud Chief Fm.
	Guadalupian	Whitehorse Group	Whitehorse Group
		Dog Creek Sh.	Dog Creek Sh.
		Blaine Fm.-evap.	Blaine Fm.
		Flowerpot Sh.	Flowerpot Sh.
		Glorieta Ss.	Duncan Ss.
	Leonardian	*Clear Fork Group.	Enid Group
		Wellington Fm.	Wellington Fm.
	Wolfcampian	*Chase Group	Chase Group
		*Council Grove Group	Council Grove Group
Carboniferous			
Pennsylvanian	Virgilian	Admire Group	Admire Group
		*Wabaunsee Group	*Wabaunsee Group
		*Shawnee Group	*Shawnee Group
		*Douglas Group	*Douglas Group
	Missourian	*Lansing Group	#Ocheleta Group
		*Kansas City Group	#Skiatook Group
		*Pleasanton Group	
	DesMoinesian	*Marmaton Group	*Marmaton Group
		*Cherokee Group	*Cherokee Group
	Atokan	Atoka Group	*Atoka Group
	Morrowan	*Morrow Fm.	*Morrow Fm.
			*Springer Fm.
Mississippian	Chesterian	*Chester Group	*Chester Group
	Meramecian	"Meramec Lime"	"Meramec Lime"
Osagean-Kinderhookian		"Osage Lime"	"Osage Lime"
	Various	Woodford Sh.	Woodford Sh.
Silurian	Various	*Hunton Group	*Hunton Group
Ordovician	Various	Sylvan Sh.	Sylvan Sh.
		Viola Fm.	*Viola Fm.
		Simpson Group	*Simpson Group
		Arbuckle Group	*Arbuckle Group
Cambrian		Reagan Ss.	Reagan Ss.
		metasediments	metasediments

* Currently producing # Potentially productive

Traps. Anticlinal trapping is important in this province. Some anticlines are very large but have low relief; closure may be only tens of feet, but fields may cover many square miles. Some anticlines developed continuously through the deposition of many units and the formation of many unconformities, thus involving many pay zones. Eroded high-relief anticlines form traps for Cambrian and Ordovician units in some areas. Faulted anticlines are a common trapping mechanism in all intervals. Faults are important for some Cambrian oil accumulations. Many unconformities are present in the region and form updip seals for some fields. Stratigraphic traps include sandstone lenses and pinch-outs. Reefs and reefal facies are common. Fracture porosity forms traps in some lower Pennsylvanian carbonates. Combination traps are common.

Potential source rocks. Carboniferous units are the most common source rocks and they are all mature. They include the Smithwick Shales, the Strawn Series, and the Mississippian Barnett Shale. Limestones in the region are additional possible source rocks.

P-440, PERMIAN BASIN

The Permian basin covers approximately 76,250 square miles and includes 51 counties in west Texas and 4 counties in southeastern New Mexico. All but 6 of these counties are currently productive of oil or gas, and the basin is a major oil and gas (both associated/dissolved and non-associated) province. Lea County, New Mexico is one of the richest oil-producing counties in the state.

The basin is bounded on the east by the Bend arch, on the north by the Amarillo-Ouachita uplift, on the west by the Sacramento Mountains, on the southwest by the Diablo platform, and on the south by the Marathon thrust belt.

Sedimentary rocks within the basin are up to 25,000 feet thick in the deepest parts of the basin. Nearly all the rocks are of Paleozoic age with a thin veneer of Mesozoic rocks at the surface. Carbonate rocks, both limestones and dolomites, are the dominant lithology. Thick bituminous shales and lenticular sandstones are interspersed with the carbonate rocks. Thick evaporite sequences were deposited during late Permian time.

Reservoir rocks. Reservoir rocks for oil and gas range in age from Cambrian through Cretaceous. Carbonate rocks form most major reservoirs, although lenticular sandstones produce in parts of the basin. Most production comes from the thick Permian section. Late Permian Guadalupian rocks, the shallowest reservoirs, have produced more than one-half of the oil produced to date in the basin. The Grayburg and San Andres Formations are the most prolific reservoir formations. Other important reservoirs are: Yates Formation, Glorieta Sandstone, Wolfcampian limestones, Cisco Group, Canyon Group, Strawn Group, Siluro-Devonian carbonates and Ellenburger Dolomite. Porosity ranges from vuggy to cavernous in shallower reservoirs to fracture porosity in deeper reservoirs and low permeability, tight, gas sands.

Traps. The major trapping mechanism in the province is anticlinal folds. Most anticlinal fields produce from several stacked reservoirs, some containing as many as 11 pay zones. The anticlines vary in size, but can be up to 16 miles by 6 miles (Eunice-Monument field). Reef and biohermal facies are the second most common trap. This includes the Capitan reef (Guadalupian). The third most common trapping mechanism is the updip pinchout of lenticular sandstone bodies. Fault traps are rare. Some slump blocks form traps. In some parts of the province, buried topographic highs form traps. Seals in the province include evaporites, shales and porosity loss due to facies changes within the carbonates.

Potential source rocks. Bituminous shales were deposited in the basin during Ordovician, Devonian, Carboniferous and Permian (Wolfcampian, Leonardian) time. These include the Woodford Shale, Barnett Shale, and Simpson Group. The shales are likely source rocks as are numerous carbonate facies throughout the province. All the source rocks in the province are mature.

Future exploration. Present exploration is concentrated in the major producing areas. Gas exploration in the deeper portions of the Delaware and Val Verde basins is very promising. The Abo and Capitan reef complexes need further investigation. Additionally, since the majority of fields are contained in the Guadalupian rocks, all the other known reservoir levels need further examination. The Ellenburger Formation and underlying Cambrian sandstones are good prospective targets.

P-430, BEND ARCH, FT. WORTH BASIN, STRAWN BASIN
Generalized Stratigraphic Section

AGE		FORMATION	
		WEST	EAST
Cenozoic	Cretaceous		
	Upper		Austin Group Eagleford Fm. Woodbine Fm.
	Lower	Segovia Fm. Fort Terrett Fm. Trinity Group	Washita Group Fredricksburg Group Trinity Group
Jurassic			
Triassic			
Paleozoic	Permian	Leonardian	
		Wolfcampian	
		Clear Fork Group Wichita Group Putnam Fm. Moran Fm. Camp Colorado Ls. Pueblo Fm. Harpersville Fm.	
Carboniferous	Pennsylvanian		
	Virgilian	Thrifty-Graham Fms. undiff. *Canyon Group *Strawn Group Smithwick Sh. *Marble Falls- -Dornick Hills Group	*Strawn Group Smithwick Sh. *Marble Falls Fm.
	Mississippian		
	Various	Barnett Fm. *Chappell Ls.	Barnett Fm.
Devonian	Various	Houy Fm.	
Silurian			
Ordovician	Various	Viola Group Simpson Group	
	Champlainian	*Ellenburger Group	*Ellenburger Group
	Canadian		
Cambrian	Various	Moore Hollow Group (Reagan)	Moore Hollow Group

* Currently producing

P-440, PERMIAN BASIN
Generalized Stratigraphic Section

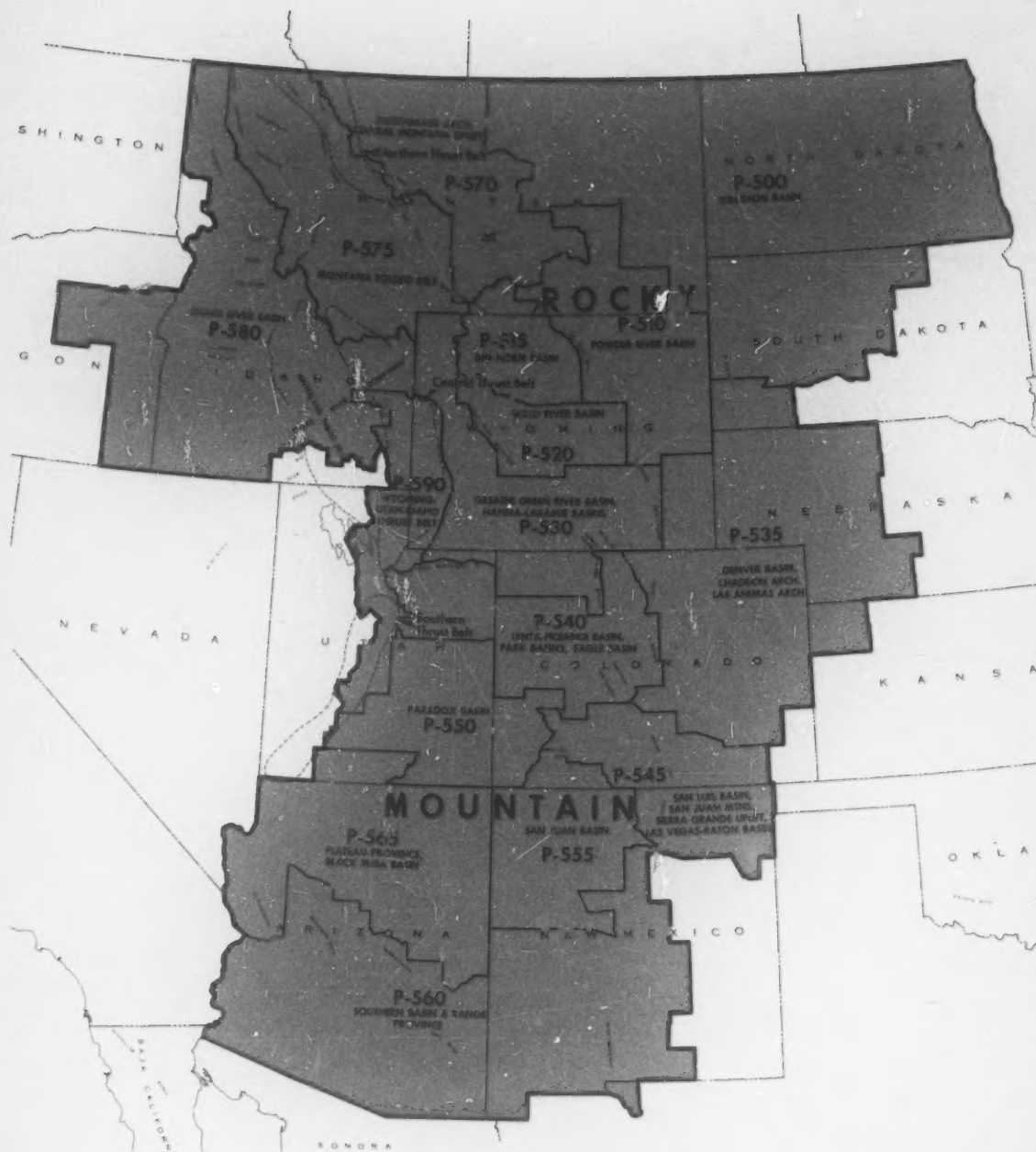
AGE		CARLSBAD - N.SHELF	BASIN - PLATFORM	EASTERN SHELF
Mesozoic				
Cretaceous				
Lower		*Edwards Ls.	*Edwards Ls.	*Edwards Ls.
			*Comanche Pk. Ls.	*Comanche Pk. Ls.
			*Paluxy Ss.	*Paluxy Ss.
		*Trinity Ss.	*Trinity Ss.	
Jurassic				
Triassic		Chinle Fm.	Chinle Fm.	Chinle Fm.
		Santa Rosa Ss.	Santa Rosa Ss.	Santa Rosa Ss.
		Tecovas Fm.	Tecovas Fm.	Tecovas Fm.
Paleozoic				
Permian	Ochoan	Dewey Lake Fm.	Dewey Lake Fm.	Dewey Lake Fm.
		Rustler Fm.	Rustler Fm.	Rustler Fm.
		Salado Fm.	Salado Fm.	Salado Fm.
	Guadalupean	Capitan Reef-Carlsbad Ls.- -Artesia Group (North) Tansil Fm. *Yates Fm. *Seven Rivers Fm. *Queen Ss. Goat Seep Reef- -*Grayburg Fm. *San Andres Dolo. *Glorieta Ss.	*Delaware Mt. Group Belle Canyon - -Artesia Group(East) Tansil Anhydrite *Yates Fm. *Seven Rivers Fm. *Queen Ss. Cherry Can. Group(West) - -*Grayburg Fm. (East) *San Andres Dolo. #Brushy Can.-*Glorieta Ss.	Artesia Group Tansil Anhyd. *Yates Fm. *Seven R. Fm. *Queen Ss.
	Leonardian	*Yaso Dolo.-varies North *Abo Sh.-Clyde Fm. *Abo Shale-Belle Plains Fm.	Bone Spring Ls.- -*Clear Fork Group	Vale Fm. Arroyo Fm. Lueders Fm. Clyde Fm. Belle Plains Fm. Admiral Fm. Putnam Fm. Moran Fm. Pueblo Fm.
	Wolfcampian	Hueco Ls. - Hueco equiv. Powow Cgl.-Peublo Fm.	*Wolfcamp Group "detrital conglomerates"	
Carboniferous	Virgilian	*Virgil Group	*Cisco Group	*Cisco Group
Pennsylvanian	Missourian	*Missouri Group	*Canyon Group-Scurry Reef Ls.	*Canyon Group
	Des Moinesian	*Des Moines Group	*Strawn Group	*Strawn Group
	Atokan	*Atoka Group	*Atoka-*Bend Groups	*Bend Group
	Morrowan	Morrow Group	Morrow Group	
	Chesterian	Helms Fm.	Helms Fm.-Barnett Sh.	
	Meramecian	Rancheria Fm.	Rancheria Fm.	#Mississippian Ls.
	Chatauquan	Woodford Sh.	Woodford Sh.	
	Various	Thirtynone Fm.	Thirtynone Fm.	
Devonian	Various	"Silurian Ls." Fusselman Dolo.	*Wristen Fm. *Fusselman Dolo.	
		Montoya Dolo.	Montoya Dolo.	
Silurian	Various		Simpson Group	
Ordovician	Canadian	Ellenburger Dolo.	*Ellenburger- -Wilburns Fms.	*Ellenburger- -Wilburns Fms.
Cambro-Ordo.		#Bliss Ss.		Cambrian Ss.

* Currently producing # Potentially productive

Table 10. Estimated resources of natural gas for provinces of the Mid-Continent Area, December 1988
(billion cubic feet)

PROVINCE	ONSHORE depth	OFFSHORE water depth	PROBABLE			POSSIBLE			SPECULATIVE		
			Min.	M. likely	Max.	Min.	M. likely	Max.	Min.	M. likely	Max.
P-400, Central Kansas uplift, Salina basin, etc. P-410, Arkoma basin	0-15,000'		300	400	600	100	100	200	*	*	*
	15-30,000'								*	*	*
	0-15,000'		2,250	3,500	4,100	1,000	1,550	1,750	1,200	1,800	2,050
P-420, Anadarko basin, Palo Duro basin, etc. P-430, Ft. Worth basin, Bend arch, Strawn basin P-440, Permian basin	15-30,000'		200	300	350	250	400	500	300	500	650
	0-15,000'		10,300	16,600	27,300	8,600	16,000	28,700	11,200	22,500	41,300
	15-30,000'		4,800	9,000	21,800	5,000	9,200	22,200	2,700	5,000	11,900
TOTAL, onshore TOTAL, onshore TOTAL, onshore, all depths GRAND TOTAL FOR AREA	0-15,000'		1,500	2,300	3,000	900	1,900	2,400	100	800	1,000
	15-30,000'		3,400	6,200	10,200	4,500	18,800	29,400	100	1,000	1,700
	0-15,000'		4,200	7,500	12,600	6,000	13,700	19,500	*	*	*
TOTAL, onshore TOTAL, onshore TOTAL, onshore, all depths GRAND TOTAL FOR AREA	0-15,000'			29,000			38,350			26,100	
	15-30,000'			16,800			23,300			5,500	
				45,800			61,650			31,600	
				45,800			61,650			31,600	

*Negligible quantity of natural gas estimated.



ROCKY MOUNTAIN AREA

The greatest potential for non-associated natural gas in the Rocky Mountain Area is concentrated in southwestern Wyoming and adjacent northwestern Colorado and northeastern Utah. This region includes the Greater Green River basin, the Uinta-Piceance basins and, to a lesser extent, the Wind River basin. All these basins have a Tertiary and Cretaceous section containing large volumes of carbonaceous and coaly sedimentary rocks in addition to marine rocks. Below a depth which generally corresponds to the 200° F isotherm, the sedimentary rocks tend to be overpressured because gas is being generated and cannot escape from the low permeability rocks. The primary criterion for locating commercial gas production is finding a reservoir which is porous, permeable and continuous. Much of the gas which has been and will be found is in reservoirs which are classified as "tight." The western Green River basin also includes the multi-trillion cubic foot accumulation of gas with low hydrocarbon content, and hence, low Btu value, found in Paleozoic sedimentary rocks on the Moxa arch. A comparable, somewhat smaller accumulation has been located below 20,000 feet on the Madden anticline in the Wind River Basin.

The second province with major natural gas potential in the Rocky Mountain Area is the Wyoming-Utah-Idaho Thrust Belt. Large accumulations have been found in the Fossil basin area located in the southwestern corner of Wyoming and adjacent northern portions of Utah. The fields are primarily on the hanging wall of the Absaroka Thrust where early Mesozoic and Paleozoic reservoirs involved in complexly faulted anticlines have been thrust eastward over Cretaceous source rocks. The Mesozoic reservoirs tend to contain sweet gas and condensate, whereas the Paleozoic reservoirs tend to contain sour gas and condensate. Reservoir rocks have been thrust over Cretaceous sedimentary rocks in other portions of this province. However, there has been sufficient exploratory drilling to show that numerous major accumulations comparable to those in the Fossil basin are not likely to exist throughout the

trend. The potential for gas derived from other possible source rocks and for production from Cretaceous sedimentary rocks is still uncertain.

The Montana Folded Belt may contain accumulations resulting from geologic relationships which are grossly comparable to those existing, and postulated to exist, in the Wyoming-Utah-Idaho Thrust Belt. The Sweetgrass arch and Central Montana uplift province contains numerous accumulations of associated and non-associated gas in a wide variety of structural and stratigraphic traps involving Paleozoic and Mesozoic reservoirs. The geologic variations found within this province provide opportunity for additional potential gas resources.

The Williston basin is primarily an oil province with most gas reserves and resources in the associated/dissolved category. Deeper accumulations within the basin tend to have higher gas/liquid ratios.

The Powder River basin of eastern Wyoming and Montana is also primarily an oil-producing region from Permo-Pennsylvanian and Cretaceous reservoirs. However, discoveries in the Amos/Andy area of Campbell County, Wyoming, are gas-condensate accumulations. Six fields, including Hilight, Kitty and Lance Creek, have produced in excess of 50 Bcf of associated gas. The Big Horn basin of Wyoming and Montana has potential for significant gas accumulations, primarily in Cretaceous sedimentary rocks in the central, deeper portions of the basin, even though current production is primarily oil from Paleozoic reservoirs around the margins of the basin.

Most of the gas in the Denver basin is contained in one major non-associated accumulation in the Wattenberg area north of Denver. This accumulation is in the Lower Cretaceous "J" sandstone and is essentially in a basin-centered stratigraphic trap on a "paleo high." The areal extent of the field is expected to expand with

further development. The development of additional gas resources is anticipated in the Upper Cretaceous Terry, Hygiene, Niobrara and Codell-Timpas intervals, plus additional associated gas with the "D" and "J" sandstone oil accumulations. Speculative resources are projected in younger Upper Cretaceous formations and in Paleozoic sedimentary rocks.

The overlapping, multi-pay accumulations of gas in Upper Cretaceous sandstones which characterize the San Juan basin constitute the largest known gas reserve in the Rocky Mountain Area. Potential resources, estimated to be trillions of cubic feet, have been assigned to this basin.

Additional accumulations, comparable to those which have been found previously, are expected in the Paradox basin. Gas/liquid ratios are expected to be higher in the deeper parts of the basin. The Snake River basin, Black Mesa basin and the Southern Basin and Range province are assigned only minor gas potential based on present information.

Estimates of potential resources for the Rocky Mountain Area are approximately 4 percent higher for the total of all resource categories than the corresponding total at the end of 1986. The change results primarily from changes in estimates for five provinces. The most likely estimates of Probable and Possible resources for the Wind River basin (province P-520) below 15,000 feet have been increased as a result of improved reservoir character demonstrated in a second deep test at Madden field. Most likely estimates of Possible resources in the Greater Green River basin (province P-530) have been increased for depths less than 15,000 feet because of the interpretation that reservoir conditions in Cretaceous rocks will be better than previously anticipated in the western part of the Green River basin. Estimates for the deep portion of the Greater Green River basin below 15,000 feet have been reduced because of information indicating poorer reservoir character than previously expected in Mesozoic rocks. The most likely estimates in the Probable and Possible categories for the Uinta and Piceance basins (province P-540) have both been increased to recognize the potential for additional resources which could be developed through infill drilling and completion in potential producing intervals currently behind casing. Estimates of Possible resources in the San Juan basin (province P-555) in the most likely category at depths less than 15,000 feet have been decreased because recent dry

holes have condemned large areas previously thought to have potential resources. The most likely estimates for the Wyoming-Utah-Idaho Thrust Belt (province P-590) have been reduced because review of available data indicates poorer reservoir character than anticipated in subthrust Cretaceous rocks.

P-500, WILLISTON BASIN

This sedimentary basin covers more than 225,000 square miles in North Dakota, South Dakota, eastern Montana, southern Saskatchewan and southwestern Manitoba. It is bounded on the east by the Canadian Shield, on the southeast by the Sioux uplift, on the southwest by the Black Hills uplift and on the west by the Big Snowy uplift. Production occurs in all three states and both Canadian provinces. More than 16,000 feet of sedimentary rocks lie in the deepest portion of the basin, and, of these, 5,000 to 7,000 feet are Paleozoic sedimentary rocks, mostly carbonates and evaporites, and 6,000 feet are Mesozoic rocks, primarily clastics.

Gas production in this basin is primarily associated with oil. Exceptions to this are found in a handful of wells in the Ordovician and Cambro-Ordovician on and near the Nesson anticline and in the Cretaceous on the Cedar Creek anticline.

The Probable resources are expected to be mostly associated gas, found within the boundaries of existing fields through field extensions. The Possible resources are expected to be mostly associated gas. Field size probably will be extremely variable, with most in the 1 to 3 Bcf range. The Speculative resources are expected to be primarily non-associated gas found in fields from 3 to 100 Bcf.

Reservoir rocks. Production occurs in reservoir formations ranging in age from Cambrian to Cretaceous. These productive units are the Cretaceous Colorado Group and Montana Group; the Permian-Triassic Spearfish Formation; the Pennsylvanian Tyler Formation; the Mississippian Big Snowy Group and Madison Group; the Devonian-Mississippian Bakken

Formation; Devonian carbonate rocks; the Silurian Interlake Formation; the Ordovician Stony Mountain, Red River and Winnipeg Formations; and the Cambrian Deadwood Formation. Cretaceous Dakota Group sandstones, as well as sandstones in the Jurassic Swift Formation, are potential reservoirs for natural gas.

Traps. Anticlines and faulted anticlines provide traps for all potential reservoirs. Stratigraphic trapping is also very important. Principal types of stratigraphic traps are porosity variations and truncations updip into impermeable units, such as evaporites. Next in importance are sandstone lenses and channels, found dominantly in the Big Snowy, Tyler and Lower Cretaceous units. Reefs, bioherms and buried topography form traps in the Red River, Interlake, Madison, and Devonian carbonate rocks. Combinations of these traps exist. Hydrodynamic trapping occurs in some anticlines.

Potential source rocks. Hydrocarbons in this basin were formed in numerous formations ranging in age from Cambrian to Paleocene. These formations include the Bakken, Red River, Winnipeg and Deadwood Formations, as well as the Paleocene Fort Union Formation; Upper Cretaceous Niobrara Formation; Lower Cretaceous Mowry Formation; Pennsylvanian Tyler Formation; Mississippian Heath and Lodgepole Formations; and Devonian Birdbear (Nisku) Formation.

Producing trends. The most noticeable structural feature in the province is the Cedar Creek anticline of southeastern Montana. This northwest-southeast-trending structure is over 100 miles long and contains up to 440 feet of productive section in lower Paleozoic carbonate rocks. Other major anticlines are the Bowdoin dome and Nesson and Billings anticlines.

P-510, POWDER RIVER BASIN

The Powder River basin is bounded on the east by the Black Hills, on the southeast by the Hartville uplift, on the south by the northwest end of the Laramie Range, on the west by the Casper arch and Big Horn Mountains, and on the north by the Miles City arch. This asymmetrical structural basin covers over 20,000

square miles. It is primarily an oil-producing basin, and natural gas represents a relatively minor portion of the basin's petroleum resources.

Large probable and possible resources of dry biogenic methane is predicted in porous fluvial-deltaic sandstones of the Fort Union Formation (Paleocene), especially in the coal-bearing Tongue River Member. Some gas production in shallow (± 300 -1,000 feet deep) Tongue River Sandstone has been developed in the last three years in the northeastern part of the basin. Very probably, the only non-associated gas will be shallow coalbed methane. The Probable resources will come from field extensions, step-outs, etc., primarily in the deeper region of the basin. The Possible resources are expected to occur in field-sizes of 5 to 300 Bcf and generally limited to the lower end of the range. Speculative resources may be found in the deeper synclinal area of the basin at 15,000 feet and greater in depth. Sizes may range from 20 to 200 Bcf.

Reservoir rocks. Potential reservoir rocks vary in age from Pennsylvanian to Cretaceous. Formations which are currently productive include the Upper Cretaceous Fox Hills Formation, Teapot Formation, Parkman Sandstone, Sussex Sandstone, Shannon Sandstone, Ash Creek Formation and Frontier Sandstone; the Lower Cretaceous Muddy-Dakota-Newcastle Formations, and Inyan Kara Group (Lakota Formation); the Jurassic Sundance Formation; and the Pennsylvanian Minnelusa-Tensleep Formations.

Traps. Anticlinal traps are common in the western portion of the basin. The central portion has buried topographic traps. The eastern portion is dominated by traps created by variations in the permeability of the reservoir rocks. Lenticular sandstones are found throughout the basin.

Potential source rocks. Organic-rich sedimentary rocks were deposited at various times during the history of the region. Potential source rocks range in age from Pennsylvanian to Paleocene. They include the Paleocene Fort Union Formation; the Upper Cretaceous Lance, Lewis, Steele, Niobrara, Frontier and Greenhorn Formations; the Lower Cretaceous Mowry and Skull Creek Shales; the Jurassic Sundance Formation; the Permian Phosphoria Formation; and the Pennsylvanian Minnelusa Formation.

P-500, WILLISTON BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	WEST	CENTRAL/EAST
Cenozoic		
Miocene	unnamed unit	unnamed unit
Oligocene	Brule Fm. Chadron Fm.	Brule Fm. Chadron Fm.
Eocene		
Paleocene	Fort Union Group	Fort Union Group
Mesozoic		
Cretaceous		
Upper	Hell Creek Fm. Montana Group Fox Hills Fm. Bearpaw Sh. Judith River Fm. Claggett Fm. *Eagle Fm. Telegraph Creek Fm. Colorado Group #Niobrara Fm. #Carlile Fm. #Greenhorn Fm. #Belle Fourche Fm.	Hell Creek Fm. Montana Group Fox Hills Fm. *Pierre Fm.
Lower	#Mowry Fm. #Muddy Ss. #Skull Creek Fm. #Dakota Fm. #Kootenai Fm. #Lakota Fm. Morrison Fm. #Swift Fm. Rierdon Fm. #Piper Fm. Nesson Fm.	Dakota Group #Mowry Fm. #Newcastle Fm. #Skull Creek Fm. #Inyan Kara Fm.
Jurassic		#Swift Fm. Rierdon Fm. #Piper Fm.
Triassic		Dunham Salt *Spearfish Fm.
Permo-Triassic	*Spearfish Fm.	
Paleozoic		
Permian	*Spearfish Fm. Minnekahta Fm. Opeche Fm. Minnelusa Fm. Amsden Formation *Tyler Fm.	Pine Salt *Spearfish Fm. Minnekahta Fm. Opeche Fm. Broom Creek Fm. Alaska Bench Mbr. *Tyler Fm.
Penn. - Permian		
Pennsylvanian		

* Currently producing #Potentially productive

P-500, WILLISTON BASIN (continued)
Generalized Stratigraphic Section

AGE	FORMATION	
	WEST	CENTRAL/EAST
Mississippian	Big Snowy Group *Heath Fm. Otter Fm. *Kibbey Fm. Madison Group *Charles Fm. *Mission Can. Fm. #Lodgepole Fm.	Big Snowy Group Otter Fm. #Kibbey Fm. Madison Group *Charles Fm. *Mission Can. Fm. #Lodgepole Fm.
Devonian-Miss. Devonian	*Bakken Fm. *Three Forks Fm. *Birdbear ("Nisku") Fm. *Duperow Fm. #Souris River Fm. #Dawson Bay Fm. Prairie Fm. *Winnipegosis Fm. Ashern Fm.	*Bakken Fm. *Three Forks Fm. *Birdbear ("Nisku") Fm. *Duperow Fm. #Souris River Fm. #Dawson Bay Fm. Prairie Fm. *Winnipegosis Fm. Ashern Fm.
Silurian	*Interlake Fm.	*Interlake Fm.
Ord. Silurian	*Stonewall Fm.	*Stonewall Fm.
Ordovician	*Stony Mt. Fm. *Red River Fm. *Winnipeg Fm.	*Stony Mt. Fm. *Red River Fm. *Winnipeg Fm.
Cambro-Ordo.	*Deadwood Fm.	*Deadwood Fm.

* Currently producing #Potentially productive

Potential for future exploration. The basin has good potential since large areas have not been explored. In explored areas, many potential reservoir rocks remain relatively untested. Many undiscovered stratigraphic traps are believed to exist.

Coalbed methane. A resource of 5.9 to 39.4 Tcf of in-place coalbed methane is estimated for the coals of the Powder River basin. No estimate of the recoverable component of this in-place resource has been made to date.

P-515, BIG HORN BASIN

This province covers approximately 11,000 square miles in northern Wyoming and southern Montana. It is primarily an oil province and most gas occurs as associated/dissolved gas although non-associated gas

is produced from Cretaceous formations as well as the Paleocene Fort Union Formation. The basin is bounded on the west by the Absaroka Range and the Beartooth Mountains, on the south by the Owl Creek Mountains, on the east by the Big Horn Mountains and on the north by the Nye-Bowler lineament. The basin is covered by Tertiary continental sedimentary rocks which are as much as 8,000 feet thick. Mesozoic sedimentary rocks are up to 9,800 feet thick. The Paleozoic section is only approximately 2,300 feet thick.

Reservoir rocks. Potential reservoir rocks range in age from Cambrian to Paleocene. The most prolific reservoirs are the Permian Phosphoria Formation (Embar Limestone Member) and the Pennsylvanian Tensleep Formation. Other reservoir formations are the Paleocene Fort Union Formation; the Upper Cretaceous Lance Formation, Mesaverde Formation and Frontier Sandstone; the Lower Cretaceous Muddy, Dakota, Lakota and Fuson Formations; the Triassic

P-510, POWDER RIVER BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	WEST	EAST
Cenozoic		
Miocene	Lower Miocene Rocks	
Oligocene	White River Fm.	
Eocene	Wagon Bed Fm.	
Paleocene	Fort Union Fm.	
Mesozoic		
Cretaceous		
Upper	*Lance Fm.	*Lance Fm.
		*Fox Hills Fm.
	Meeteetse Fm.	Pierre Sh.
	*Mesaverde Fm.	
	*Cody Sh.	*Niobrara Fm.
		Carlile Fm.
	*Frontier Fm.	Greenhorn Fm.
		Bell Fourche Sh.
Lower	*Mowry Sh.	*Mowry Sh.
	*Muddy Ss.-	*Newcastle Ss.
	-Thermopolis Sh.	Skull Creek Sh.
	Cloverly Fm.	Inyan Kara Group
		*Fall River Fm.
		*Lakota Fm.
Jurassic	Morrison Fm.	Morrison Fm.
	*Sundance Fm.	*Sundance Fm.
	Gypsum Springs Fm.	Gypsum Springs Fm.
Triassic	Chugwater Fm.	Spearfish Fm.
Paleozoic		
Permian	Goose Egg-	Minnekahta Ls.
	-Phosphoria Fm.	Opeche Sh.
Pennsylvanian	*Tensleep Ss.	*Minnelusa Fm.
Mississippian	*Amsden Fm.	
	#Madison Ls.	Pahasapa Ls.
		Englewood Ls.
Devonian	Darby Fm.	
Ordovician	#Bighorn Dolo.	Whitewood Dolo.
Cambrian	Gallatin Ls.	Winnipeg Fm.
	Gros Ventre Fm.	#Deadwood Fm.
	Flathead Ss.	Flathead Ss.

* Currently producing # Potentially productive

Chugwater and Curtis Formations; the Pennsylvanian Amsden Formation (Darwin Sandstone Member); the Mississippian Madison Limestone; the Devonian Darby Formation; the Ordovician Big Horn Dolomite; and the Cambrian Flathead Sandstone.

Traps. The major traps are anticlines and faulted anticlines, often combined with changes in porosity and permeability of reservoir formations. Many reservoirs demonstrate tilted oil/water or gas/water contacts due to hydrodynamic flow of water through the permeable formations. Channel and lenticular sandstones occur as well as facies changes in the carbonate reservoir rocks.

Potential source rocks. Potential source rocks occur at several stratigraphic levels, including the Paleocene Fort Union Formation; the Upper Cretaceous Lance, Mesaverde, Cody, Niobrara and Frontier Formations; the Lower Cretaceous Mowry and Thermopolis Shales; the Permian Phosphoria Formation; and in Upper Devonian rocks.

Future exploration. To the present time, exploration has concentrated on anticlinal structures in the basin and the main target formations have been the Pennsylvanian-Permian units. Future targets include possible stratigraphic traps and the thick Mesozoic section, especially the various sandstones within the Mesaverde, Frontier and Dakota Formations.

P-520, WIND RIVER BASIN

This central Wyoming basin is bounded on the west and southwest by the Wind River Mountains, on the south by the Granite Mountains, on the north by the Owl Creek Mountains and the Washakie Range and on the east by the Casper arch. The basin covers approximately 8,500 square miles. Approximately three-fourths of the basin contains more than 20,000 feet of Paleocene-Eocene sedimentary rocks, and up to 30,000 feet of total sedimentary section occurs in the deeper portions of the basin. The basin was emergent during much of Paleozoic time, thus very little Paleozoic section exists and there is nearly four times as much Mesozoic section as Paleozoic.

Structural features include a series of north-northwest-trending folds along the southern flank of the basin. Along the northern flank, rocks of the Owl Creek Mountains have been thrust southward over younger sedimentary rocks of the basin and on the east the Casper arch is thrust west over sedimentary rocks.

Natural gas in the Wind River basin occurs as both associated/dissolved gas and as nonassociated gas. Most of the gas resource is nonassociated. Many fields produce from multiple reservoirs. A multi-billion cubic foot accumulation in the Mississippian Madison Limestone has been discovered by a well on the Madden anticline below 20,000 feet.

Reservoir rocks. The major developed reservoir formation in the basin is the Pennsylvanian Tensleep Formation, but additional formations produce gas and/or oil in the basin, including the Tertiary Wind River and Fort Union Formations; the Upper Cretaceous Lance, Mesaverde, Cody and Frontier Formations; the Lower Cretaceous Muddy, Dakota, Cloverly-Lakota Formations; the Jurassic Morrison and Sundance-"Curtis" Formations; the Triassic Nugget and Crow Mountain Formations; the Permian Phosphoria Formation (Embar Limestone Member) and the Mississippian Madison limestone. Many of the Tertiary and Upper Cretaceous reservoirs fall in the "tight" classification.

Traps. Anticlines and faulted anticlines form traps in all stratigraphic intervals. Sandstone channels and lenses are common. Porosity and permeability changes and pinchouts are also abundant in all intervals.

Potential source rocks. Potential source rocks range in age from Permian to Tertiary. They include the Tertiary Fort Union-Waltman Formations; the Upper Cretaceous Lance, Mesaverde, Cody, Niobrara and Frontier Formations; the Lower Cretaceous Mowry and Thermopolis Shales; and the Permian Phosphoria Formation.

Future exploration. The Wind River basin is in an intermediate stage of exploration. Potential targets exist in stratigraphic traps and in untested intervals within all parts of the stratigraphic section. Undiscovered traps and potential reservoirs are believed to exist along the northern and eastern flanks of the basin in sedimentary rocks beneath thrust faults.

P-515, BIG HORN BASIN
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Eocene	Wapiti-Aycross Fms. Tatman-Willwood Fms.
Paleocene	*Fort Union Fm.
Mesozoic	
Cretaceous	
Upper	*Lance Fm. *Meeteetse Ss.-Lewis Sh. Mesaverde Fm-Teapot Ss. Mbr. Mesa Verde Fm. Cody Sh.
Lower	*Frontier Fm. Mowry Sh. *Thermopolis-Muddy Ss. Mbr. Thermopolis Sh. *Cloverly Fm.
Jurassic	Morrison Fm. *Sundance Fm. Gypsum Spring Fm. Nugget Ss.
Triassic	Chugwater Group Papo Agie Fm. Crow Mountain Ss. Alcova Ls. Red Peak Fm.
Paleozoic	
Permian	*Dinwoody-Phosphoria (Goose Egg Fm.)
Pennsylvanian	*Tensleep Ss. *Amsden Fm.
Mississippian	*Madison Ls.
Devonian	*Darby Fm.
Silurian	
Ordovician	Bighorn Dolo.
Cambrian	Gallatin Ls. Gros Ventre Fm. *Flathead Ss.

* Currently producing # Potentially productive

Coalbed methane. A resource of 0.5 to 2.2 Tcf of in-place coalbed methane is estimated for the coals of the Wind River basin. No estimate of the recoverable component of this in-place resource has been made to date.

P-530, GREATER GREEN RIVER BASIN, HANNA AND LARAMIE BASINS

The Greater Green River basin extends over parts of southwestern Wyoming, northeastern Utah and

P-520, WIND RIVER BASIN
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Miocene	Split Rock Fm.
Oligocene	White River Fm.
Eocene	Wagon Bed-Teepee-Aycross Fms. *Wind River Fm. Indian Meadows Fm. *Fort Union Fm.
Paleocene-Eocene	
Mesozoic	
Cretaceous	
Upper	*Lance Fm. #Meeteetse Fm. - Lewis Sh. *Mesaverde-Teapot Ss.Mbr. Mesaverde-Parkman Ss. Mbr. *Cody-Steel-Niobrara Fm. *Frontier Fm.
Lower	Mowry Sh. *Muddy Ss.Mbr., Thermopolis Sh. Thermopolis Sh. *Cloverly Fm.
Jurassic	*Morrison Fm. *Sundance Fm. Gypsum Spring Fm. *Nugget Ss.
Triassic	Chugwater Group Papo Agie Fm. *Crow Mountain Fm. Alcova Ls. Red Peak Fm. Dinwoody Fm.
Paleozoic	
Permian	*Phosphoria Fm.
Pennsylvanian	*Tensleep Fm. #Amsden Fm. *Madison Ls.
Mississippian	*Darby Fm.
Devonian	Bighorn Dolo.
Ordovician	Gallatin Ls.
Cambrian	Gros Ventre Fm. Flathead Ss.

*Currently producing # Potentially productive

northwestern Colorado. The province includes several smaller basins in addition to the Green River basin proper: Red Desert basin, Washakie basin, Sand Wash basin, Hanna basin, Kindt basin, Shirley basin and Laramie basin. Approximately 27,000 square miles of prospective sedimentary basins are included in this province which is bounded on the west by the Utah-Wyoming-Idaho Thrust Belt, on the north by the Wind River and Granite Mountains, on the east by the Laramie Range and on the south by the Uinta Mountains and the Axial Basin anticline. The Green River basin proper contains more than 20,000 feet of Paleocene-Eocene continental sedimentary rocks. The total sedimentary section is over 30,000 feet thick.

Even though about 11,000 wells have been drilled in the province, large areas are still sparsely tested and vast areas are virtually untested below the shallowest of several prospective stratigraphic horizons. Throughout much of the basin, the Frontier, Dakota and Paleozoic Formations are at an early stage of exploration. Even the lower part of the Mesaverde Group is largely undrilled throughout much of the Green River, Red Desert and Washakie basins.

The Probable resources are expected to be found in field and trend extensions dominated by the LaBarge Platform, Moxa Arch and Wamsutter Arch/Washakie basin complexes. Methane from low-Btu gas entrapped in Paleozoic reservoirs of the LaBarge Platform comprises much of the Probable and Possible resources. The Possible resources are expected to be found in fields ranging in size from 2 to 1,000+ Bcf with many of them in the 5 to 50 Bcf range. The Speculative resources are expected to be found in fields ranging in size from 2 to 1,000 Bcf with the most likely size being between 10 to 200 Bcf.

Reservoir rocks. Potential reservoir rocks range in age from Cambrian to Eocene. The major producing formations are sandstones of the Tertiary Wasatch and Fort Union Formations; the Upper Cretaceous Lewis, Mesaverde Group (including the Almond), Frontier Formation; the Lower Cretaceous Dakota Group; the Juro-Triassic Nugget Sandstone and the Mississippian Madison Limestone. Other reservoirs include the Upper Cretaceous Lance-Fox Hills, the Baxter and Steele shales; the Muddy sandstone, the Jurassic Morrison and Sundance, the Permian Phosphoria Formation; the Permo-Pennsylvanian Weber-Tensleep, the Pennsylvanian Amsden and Morgan Formations and the Cambrian Flathead Sandstone. Many potential reservoir rocks have low permeability.

Traps. Anticlines and faulted anticlines provide traps for reservoirs of all ages. Together with the structural traps, sandstone pinchouts and permeability changes form the major trapping mechanisms. Combination sandstone pinchout-fault traps are productive in some areas.

Potential source rocks. Potential source rocks range in age from Mississippian to Eocene. They include the Eocene Wasatch and Green River Formations; the Paleocene Fort Union Formation; the Upper Cretaceous Lance, Mesaverde, Lewis, Baxter-Niobrara

and Greenhorn Formations; the Lower Cretaceous Mowry-Aspen and Thermopolis Shales; Jurassic shales; Permian Phosphoria Formation; and Mississippian shales and carbonates. Paleocene and Upper Cretaceous coalbeds are major sources of gas and condensate in the deep parts of the basins.

Future exploration. Although the Greater Green River basin is a major natural gas province, it is still lightly explored. Throughout an area of 13,000 square miles, the Cretaceous Frontier and Dakota sandstones have been penetrated in only one percent of the sections. Thrusting of Precambrian rocks over the northern and southern margins of the basins and fractured reservoirs along lineament trends could prove to be of exploration interest. Future exploration will require adequate economic incentives, presently lacking, in order to justify pursuit of subtle stratigraphic traps in deep, low-permeability reservoirs. Most of the deep gas will be produced from depths of less than 20,000 feet. Exploitation of methane contained in low-Btu gas of the LaBarge Platform/Moxa Arch Paleozoic reservoirs is dependent upon the economics of tertiary recovery of oil using the major component of the gas-carbon dioxide.

Coalbed methane. A resource of 0.2 to 30.9 Tcf of in-place coalbed methane is estimated for the coals of the Greater Green River basin. No estimate of the recoverable component of this in-place resource has been made to date.

P-535, DENVER BASIN, CHADRON ARCH AND LAS ANIMAS ARCH

This province covers over 95,000 square miles and includes three widely different geological features: the Denver basin, the northern portion of the Las Animas arch and the Chadron-Cambridge arches complex. The Denver basin is a north-south asymmetrical sedimentary basin lying in eastern Colorado, southwestern Nebraska and southeastern Wyoming. It is bounded on the southeast by the Las Animas arch, on the northeast and east by the Chadron-Cambridge arches, on the north and northwest by the Hartville uplift, on the west

P-530, GREATER GREEN RIVER BASIN, HANNA AND LARAMIE BASINS
Generalized Stratigraphic Section

AGE	FORMATION		
	WEST	CENTRAL	EAST
Cenozoic			
Miocene	Miocene Rocks	Miocene Rocks	Miocene Rocks
Oligocene	Conglomerate	Bishop Cgl.	#White River Fm.
Eocene	#Bridger Fm. #Green River Fm.		Wagon Bed Fm. Wind River Fm.
Paleocene	Hoback Fm.	*Fort Union Fm.	*Hanna Fm. #Ferris Fm.
Mesozoic			
Cretaceous		#Lance Fm.	*Medicine Bow Fm.
Upper		Fox Hills Ss. Lewis Sh. *Almond Fm. *Ericson Fm. *Rock Springs Fm. *Blair Fm. *Baxter Sh.	#Fox Hills Ss. *Lewis Sh. Mesaverde Group *Steele Sh. *Niobrara Fm.
	Adaville Fm. *Hilliard Fm.		*Frontier Fm.
Lower	*Frontier Fm. *Aspen Sh. Bear River Fm.	*Frontier Fm. *Mowry Sh. *Muddy Ss. Mbr. Thermopolis Sh.	*Frontier Fm. *Mowry Sh. *Muddy Ss. Mbr.
	*Cloverly Fm.	*Cloverly Group	*Cloverly Fm.
Jurassic	*Morrison Fm. Curtis Fm. Entrada Ss. Twin Creek Ls. *Nugget Ss.	*Morrison Fm. Curtis Fm. Entrada Ss. Carmel Fm.	*Morrison Fm. *Sundance Fm.
Triassic	Ankareh Fm. Thaynes Fm. Woodside Fm. Dinwoody Fm.	*Nugget Ss. Ankareh Fm. Red Peak-Woodside Fm. Dinwoody Fm.	*Nugget Ss. Jelm Fm. Chugwater Fm.
Paleozoic			
Permian	*Phosphoria Fm.	*Phosphoria Fm.	#Goose Egg Fm.
Pennsylvanian	*Weber Ss.	Weber-Tensleep Ss.	#Casper Fm.
Miss.-Penn.	Amsden Fm.	*Morgan Fm. Round Valley Fm.	
Mississippian	*Madison Ls.	*Madison Ls.	*Madison Ls.
Devonian	Darby Fm.	Darby Fm.	
Silurian	Laketown Dolo.		
Ordovician	Bighorn Dolo.	Bighorn Dolo.	
Cambrian	Gallatin Ls. Gros Ventre Fm. *Flathead Ss.	Buck Springs Fm. *Flathead Ss.	Cambrian Rocks

* Currently producing # Potentially productive

by the Laramie Mountains and the Front Range and on the south by the Apishapa uplift. More than 13,000 feet of sedimentary rocks, mostly of Cretaceous age, lie in the deepest portion of the basin, below the city of Denver. The rocks thin to less than 6,000 feet on the gently dipping eastern flank of the basin. Both associated and non-associated gas are found in all parts of the basin, while dry gas is limited to the shallow eastern side. This basin also includes the Canon City embayment which contains the second oldest oil field in the United States, discovered in the spring of 1862.

The Las Animas arch is a Late Cretaceous-age uplift that extends northeasterly from southeast Colorado through northwest Kansas into south central Nebraska where it terminates in the Cambridge arch which runs perpendicular to the Las Animas arch. Depth to the Precambrian basement is about 6,000 feet along the Las Animas arch and ranges from more than 5,000 feet to zero along the Chadron-Cambridge arches. The latter arches form the northwest extension of the Central Kansas uplift, and they terminate to the north in the Black Hills uplift.

The Denver basin accounted for over 96 percent of the 108 Bcf of gas that has been produced during 1987 in this province. The amount produced from the Las Animas arch was slightly less than 4 percent. Three-tenths of a Bcf was produced from the Chadron arch, all of it in South Dakota.

Probable resources are expected to be found in field extensions of Cretaceous and Pennsylvanian sedimentary rocks. In order of estimated magnitude of future potential, starting with the largest, they are: the "J" sandstone, Niobrara chalk, Codell, Plainview-Lytle, Terry and Hygiene, Morrow, Leo, and "D" sandstones. Possible resources are expected to be discovered in the same rock units. Field sizes should range from one-half to 500 Bcf with most of them averaging 2 to 50 Bcf. Production of Possible resources should be concentrated within the deep, axial section of the Denver basin, the southeast Colorado segment of the Las Animas arch and the South Dakota portion of the Chadron arch. Shallower pool, and, to a lesser extent, deeper pool discoveries will be significant. Speculative resources will most likely come from presently unproductive sandstones, siltstones and carbonates of the Upper Cretaceous and Upper Paleozoic ages. Many of these reservoirs will be shaley, and have low permeability.

Reservoir rocks. The only dry gas in this province comes from the tight reservoirs of the Niobrara Formation chalks along the eastern side of the Denver basin and from adjacent parts of the Las Animas and Cambridge arches. This "tight gas" accounted for about 12 percent of the province's 1987 gas production. The most significant reservoir rock in the basin is the Lower Cretaceous "J" sandstone of the Dakota Group, also a tight reservoir in the Wattenberg area. The non-associated, wet gas produced from the "J" sandstone in the Denver Basin accounted for 34 percent of the 1987 production. In the Wattenberg area, large volumes of gas are also produced from deeper and shallower pool sandstones and fractured marls over a 4,000 foot interval. In this western and deepest part of the Denver basin, important reservoirs are located in the Upper Cretaceous strata. They include the shelf and offshore marine sandstone complexes of the Terry, Hygiene and Codell sandstones and the fractured marls and chalks of the Niobrara Formation. These reservoirs accounted for 38 percent of the gas produced in 1987. Over 10 percent of the province's gas came from numerous, rather small (about 2 to 5 Bcf average size), "J" and "D" sandstone fields in northeast Colorado, Nebraska and Wyoming. These reservoirs have porosities that approach 30 percent on the shallow east flank and become progressively less porous toward the deeper west. Minor gas reservoirs are found in the Upper Cretaceous Parkman sandstones and Greenhorn limestones, the Lower Cretaceous Plainview-Lytle sandstones and the Permian Lyons sandstones.

Very few wells in the Denver basin have been drilled below the Lower Cretaceous section. A recent play, centered in southwest Nebraska and northeast Colorado, is aimed at testing upper Paleozoic rocks. Some excellent oil reservoirs have been found in Permian- and Pennsylvanian-age clastics and carbonates. A little associated gas has also been discovered. Other potential reservoirs exist in tight, fractured marls, siltstones and shales of Cretaceous age and in the Mississippian, Devonian, Ordovician and Cambrian age strata.

The principal gas reservoir on the Las Animas arch is the Lower Pennsylvanian Morrow sandstone which contributed less than 4 percent of the gas produced in the province during 1987. Some minor gas is associated with the multiple oil reservoirs, dominantly carbonates, ranging from Mississippian through Permian in age.

P-535, DENVER BASIN, CHADRON ARCH AND LAS ANIMAS ARCH
Generalized Stratigraphic Section

AGE	FORMATION		LAS ANIMAS ARCH
	DENVER BASIN WEST	EAST	
Cenozoic			
Miocene	Ogalalla Group	Ogalalla Group	
	Arikaree Group	Arikaree Group	
Oligocene	White River Group	White River Group	
Eo.-Paleo.	#Denver Fm.- -Green Mt. Cgl.	Green Mt Cgl.- -Dawson Fm.	
Mesozoic			
Cretaceous			
Upper	Arapahoe Fm. #Laramie Fm. Fox Hills Fm. *Pierre Sh. #Richard Ss Mbr.- ("Teapot") *Larimer- -Rocky Ridge Ss. Mbrs.- ("Parkman") *Terry Ss Mbr.- -"(Sussex)" *Hygiene Ss Mbr.- -"(Shannon)" *Niobrara Group *Smoky Hill Sh. Mbr. Ft. Hayes Ls. Mbr.- -(Timpas) Benton Group #Carlile Sh. *Codell Ss. Mbr. *Greenhorn Fm. #Graneros Sh. Mowry Sh.	Arapahoe Fm. Laramie Fm. Fox Hills Fm. #Pierre Sh. *Niobrara Group *Smoky Hill Sh Mbr. Ft. Hayes Ls. Mbr. Benton Group #Carlile Sh. *Codell Ss. Mbr. *Greenhorn Fm. #Graneros Sh.	#Pierre Sh. *Niobrara Fm. *Smoky Hill Sh. Mbr. #Carlile Fm. *Codell Ss. Mbr. *Greenhorn Ls. #Graneros Sh.
Lower	*Dakota Group *"D" Ss, Mbr. *"J" Sss, Mbr. *Plainview-Lyttle Fms.	*Dakota Group *"D" Ss, Mbr. *"J" Sss, Mbr.	Dakota Group Purgatoire Fm.- -Cheyenne Ss.
Jurassic	Morrison Fm. Ralston Creek Fm. Entrada Ss. (Sundance) Jelm Fm.	Morrison Fm. Ralston Creek Fm.	Morrison Fm. Ralston Creek Fm. Entrada Ss. Dockum Group
Triassic	Lykins Fm. (upper)		
	*Currently producing #Potentially productive		

P-535, DENVER BASIN, CHADRON ARCH AND LAS ANIMAS ARCH (continued)
Generalized Stratigraphic Section

AGE	DENVER BASIN		LAS ANIMAS ARCH
	WEST	EAST	
Paleozoic Permian		#Forelle Ls.	Day Creek Dolo. Whitehorse Fm.
	Lykins Fm. (lower)		Nippewalla Group
	*Lyons Fm.-Satanka Sh.	Nippewalla Group Wellington Group	Sumner Group
	Ingelside Fm. #Fountain Fm.	*Wolfcamp Fm.	Chase Group Council Grove Group
Pennsylvanian	#Fountain Fm.	*Virgil Age	Admire Group Wabaunsee Fm.
			*Shawnee Fm.
			*Douglas Fm.
		*Missouri Age	*Lansing Fm.
		*"Leo" Ss.	*Kansas City Fm.
		*Des Moines Age	Pleasanton Group
Mississippian			*Marmaton Fm.
			*Cherokee Fm.
		#Atoka Fm.	#Atoka Fm.
		#Morrow Fm.	*Morrow Fm.
	Beulah Ls.		*Ste. Genevieve Fm.
	Hardscrabble Ls.	St. Louis Ls.	*St. Louis Fm.
Ordovician	Leadville Ls.	#Salem Fm.	*Spergen Fm.
		Warsaw Fm.	*Warsaw Fm.
		#Osage Group	*"Osage" Group
			Gilmore City Ls.
		#Kinderhook Group	#Kinderhook Sh-
			Misener Ss.
Cambrian	#Fremont Ls.		Viola Fm.
	#Harding Ss.		Simpson Group
	#Manitou Ls.	#Arbuckle Group	#Arbuckle Group
	#Peerless Fm.	#Reagan Ss.	Reagan Ss.
	Sawatch Quartzite		

*Currently producing #Potentially productive

Along the Chadron-Cambridge arches, very little associated gas comes from the many oil fields producing within Pennsylvanian carbonates and clastics. One exception is the Leo sandstones (Minnelusa equivalent) of Pennsylvanian age from which associated gas is produced in South Dakota. Several undeveloped accumulations of shallow gas have been found in the Niobrara Formation chalks and in the Dakota Group sandstones.

Traps. In the Denver basin, the major traps are formed by rapid stratigraphic changes, but important accumulations are also derived from structures, structural-stratigraphic features and fractures. Marine shales form the principal seals. Anticlines and faulted structural traps are confined to the mountain fronts in the west, and to the east central and east portions of the basin. The eastern, shallow Niobrara Formation chalks produce gas from complex, highly faulted structures capped by a 10- to 30-foot thick bentonite seal. Fractures have enhanced production from the low permeability rocks in the deep Denver basin and from the tight, shallow chalks to the east.

Basement tectonic movements formed the structures, caused the fracturing and controlled the depositional patterns in the sedimentary rocks. The Cretaceous-age sandstones were deposited in a broad variety of clastic environments ranging from coastal and deltaic to offshore marine.

Morrow sandstones were deposited in valley-fill, estuarine and marine shelf environments in the Las Animas arch area. The Leo sandstones were part of a coastal colian/sabkha depositional system. Carbonate biohermal and structural traps are prevalent in the Permian- through Mississippian-age fields along the Las Animas and Chadron arches.

Potential source rocks. Cretaceous marine shales are the dominant source rocks for the region. The major ones are found in the Niobrara Formation and the Mowry and Huntsman Shales. Also contributing hydrocarbons are the Carlile, Graneros and Skull Creek shales and the Greenhorn Limestone. These source beds are mature only in the deepest portion of the Denver basin, generally below 6,000 feet. Regional igneous thermal activity related to the Colorado Mineral Belt of the Transcontinental Arch also contributed to source rock maturity. Some gas has migrated updip to fields over 100 miles to the east from the downdip

mature areas. Vertical migration of over 2,500 feet has also been noted. The shallow eastern Niobrara formation gas has a biogenetic source rather than a thermal one. Permian and Pennsylvanian cyclic black marine shales constitute the source beds for the Las Animas and Chadron arches and for the Paleozoic production in the Denver basin.

P-540, UINTA AND PICEANCE BASINS, PARK BASINS AND EAGLE BASIN

This province contains six basins: Uinta, Piceance, Eagle, North Park, Middle Park and South Park. Hydrocarbons produced in the region are oil, associated/dissolved gas and non-associated gas. Large amounts of both oil and gas are produced in the Uinta basin. The Piceance basin is predominantly a gas province and may have the potential to be a nearly continuous gas field similar to that which occurs in the San Juan basin, however, recovery per well is expected to be small.

The Uinta basin is the largest and most highly productive portion of the province. It is bounded on the north by the Uinta Mountains, on the west by the Wasatch Range, on the south by the San Rafael swell and Uncompahgre uplift, and on the east by the Douglas Creek arch. The axis of this asymmetric, east-west trending basin lies in the northern portion of the basin. Sedimentary rocks are more than 30,000 feet thick in this region; more than 11,000 feet of these are Tertiary continental and lacustrine deposits. Major downwarping of the basin occurred during the late Cretaceous and Eocene.

The Piceance basin is the second largest and second most productive portion of the province. It is bounded on the west by the Douglas Creek arch, on the north by the Axial Basin anticline, on the east by the White River uplift and on the southwest by the Uncompahgre uplift. Up to 27,000 feet of sedimentary rocks were deposited in the deepest portion of the basin. Most fields in this region produce from more than one interval; some have up to six reservoirs. Rangely field, which lies on the Douglas Creek arch, is the only giant oil and gas field in Colorado.

Eagle and North Park basins continue to be areas of exploration interest. Small amounts of both oil and gas are produced in these basins. South Park and Middle Park contain no production at this time. South Park has some potential for production. Middle Park has very little potential.

Cumulative gas production from this province exceeds 3,000 Bcf. More than 75 percent of the production comes from reservoirs ranging from Early Cretaceous to Early Tertiary in age. In the Uinta and Piceance basins, only 10-15 percent of the potentially productive area has been adequately tested through the Cretaceous section. Possible Cretaceous objectives remain virtually undrilled in the deeper portions of the Uinta basin, while large tracts underlain by potential Tertiary and Cretaceous reservoirs remain untested in the central Piceance basin. Short-range future activity will focus on these plays as well as extension, in-field and new pool exploratory drilling within existing fields. Recent gas-condensate discoveries within Pennsylvanian-aged rocks should stimulate drilling activity for these reservoirs, particularly along basin margins.

Probable resources are expected to be found mostly in field extensions and new pool discoveries within existing fields. Possible resources are to be found in fields ranging in size from 1 to 200 Bcf with most fields falling within the 2 to 20 Bcf range. The size of fields for speculative resources should range from 10 to 1,000 Bcf with an average field size of around 100 Bcf.

Reservoir rocks. The Eocene Green River and Wasatch Formations are the primary reservoirs in the Uinta basin as well as being important units in the Piceance basin. In the Park basins, some production is from the Paleocene Coalmont Formation. Cretaceous reservoirs in this province are the Mesaverde, Mancos, Frontier, Codell, Dakota, Muddy and Lakota sandstones. Some fields produce from fractured Pierre and Niobrara intervals. Jurassic sandstone reservoirs are the Morrison and Entrada Formations. Productive Paleozoic units are the Permian Phosphoria Formation, Pennsylvanian-Permian Weber Sandstone, and Pennsylvanian Minturn Formation.

Traps. Stratigraphic traps are very important in this province, including deltaic lenses, channel and bar sands, permeability pinchouts and asphalt seals. Present production from stratigraphic traps is confined to Cretaceous and Paleocene rocks. Traditional structural

traps in the province are fault traps, anticlines and faulted anticlines which affect all stratigraphic intervals. Unconformity surfaces form traps in the Weber and Phosphoria Formations.

Potential source rocks. Source rocks in the Uinta, Piceance and Eagle basins range in age from Mississippian to Eocene. All are mature in certain areas. These source units are the Eocene Wasatch and Green River formations; Upper Cretaceous Mesaverde Group and Mancos Shale; Pennsylvanian Phosphoria and Belden shales, Mississippian Manning Canyon Shale and Deseret Limestone. Possible source rocks for the Park basins are the Cretaceous Niobrara, Greenhorn, Mowry and Thermopolis formations.

Coalbed methane. A resource of 30.0 to 110.0 Tcf of in-place coalbed methane is estimated for the coals of the Piceance basin. The most likely estimate of recoverable resource for the Piceance basin is 29.7 Tcf. The estimate for in-place resources in the Uinta basin is 0.2 to 0.8 Tcf. No estimate has been made of the recoverable resource for the Uinta basin.

P-545, SAN JUAN MOUNTAINS, SAN LUIS BASIN, LAS VEGAS-RATON BASIN, SIERRA GRANDE UPLIFT

This region of southern Colorado and northeastern New Mexico contains two structural basins, two structural arches and two mountain ranges. Present production is restricted to minor amounts of non-associated gas which is scattered through the province. Most of the production is located in the northern part of the Las Vegas-Raton basin. Two fields are located on the Apishapa uplift and one field lies at the southern nose of the Uncompahgre Mountains in Ouray County, Colorado. The Las Vegas-Raton basin contains over 7,200 feet of sedimentary rocks ranging in age from Devonian to Holocene. The San Luis basin is considered a northern extension of the Rio Grande Rift and is cross-cut by numerous fault blocks. Total sediment thickness, which may exceed 20,000 feet, varies greatly over these blocks. Much of the San Luis basin and the Sierra Grande arch are covered with volcanics. Carbon

P-540, UINTA-PICEANCE BASINS, PARK BASINS AND EAGLE BASIN
Generalized Stratigraphic Section

AGE	FORMATION		
	UINTA BASIN	PICEANCE BASIN	EAGLE, ETC. BASINS
Cenozoic			
Eocene	Duchesne R.Fm. *Uinta Fm. *Green River Fm.	Green River Fm.	
Paleocene	North Horn- *Wasatch Fm.	*Wasatch Fm. Ohio Creek Fm.	
Mesozoic			
Cretaceous	*Mesa Verde Group Mancos Shale *Frontier Ss. Mbr. Mowry Sh. *Dakota Ss. *Cedar Mt. Fm.	*Mesa Verde Group Mancos Sh. *Frontier Fm. Mowry Sh. *Dakota Group Burro Canyon Fm. Morrison Fm. & Salt Wash Mbr. #Curtis Fm. #Entrada Ss.	Mancos Sh. *Dakota Ss. Burro Canyon Fm. *Morrison Fm. #Entrada Ss.
Jurassic	*Morrison Fm. Curtis Fm. *Entrada Ss. Carmel Fm. Nugget Ss.	Navajo Ss. Chinle Fm. #Shinarump Ss. Mbr.	 Chinle Fm. #Entrada Ss.
Triassic	Chinle Fm. Gartra Grit Fm.	Chinle Fm. #Shinarump Ss. Mbr.	Chinle Fm.
Paleozoic			
Permian	Moenkopi Fm. Park City Fm. *Upper Weber Ss.	Moenkopi Fm. Phosphoria Fm. *Upper Weber Ss.	*State Bridge Fm. Maroon Fm. Eagle Valley Fm.
Pennsylvanian	*Lower Weber Ss. Morgan Fm. Round Valley Ls.	*Lower Weber Ss. *Minturn Fm. #Belden-Maroon Fm.	Minturn-Gothic Fm. #Belden Fm.
Mississippian	Doughnut Fm. *Humbug Fm. Deseret Ls. Gardison-Madison Ls.	#Leadville Ls.	#Leadville Ls.
Devonian		Chaffee Fm.	Chaffee Group Gilman Ss. Dyer Dolo. Parting Fm.
Ordovician			Fremont Ls. Harding Ss. Manitou Ls. Peerless Fm. Sawatch Quartzite
Cambrian	Lodore Ss. Maxfield Ls. Ophir Fm. Tintic Quartzite	Manitou Fm. Dotsero Fm. Sawatch Ss.	

* Currently producing # Potentially productive

dioxide is produced from Jurassic sandstones and Pennsylvanian-Permian arkoses in Harding County, New Mexico. Helium, nitrogen and carbon dioxide are produced from the Permian at the Model Dome field on the Apishapa uplift.

Reservoir rocks. Potential reservoir rocks range in age from Pennsylvanian to Paleocene. They include the Cretaceous-Paleocene Raton Formation; the Upper Cretaceous Vermejo Formation, Trinidad Sandstone, fractured Niobrara Formation, Coal Sandstone Dakota equivalents; the Jurassic Entrada Sandstone; the Permian Glorieta Sandstone; the Pennsylvanian-Permian Sangre de Cristo Formation; and the Pennsylvanian Madera Limestone.

Traps. Stratigraphic traps may be found in most intervals. These include sandstone lenses and porosity pinchouts. Structural traps include anticlines, faulted anticlines and reverse faults. Combinations of these traps may exist.

Potential source rocks. The most likely source rocks in the province are the Raton and Vermejo Formations and Colorado Group. Paleozoic carbonate rocks may also be source beds in parts of the province.

Coalbed methane. A resource of 8.0 to 18.4 Tcf of in-place coalbed methane is estimated for the coals of the Raton basin. No estimate of the recoverable resource has been made.

P-550, PARADOX BASIN

This province covers most of southeastern Utah and part of southwestern Colorado and contains three major producing regions: the Paradox basin, the Uncompahgre uplift and the San Rafael Swell. The Paradox basin is a sedimentary basin containing more than 24,000 feet of sedimentary rocks ranging in age from Cambrian to Tertiary. The basin is bounded on the west and southwest by the San Rafael Swell and the Monument uplift, on the southeast by the Four Corners Platform, and on the east and northeast by the Uncompahgre uplift. Major downwarping of the basin oc-

curred during the Pennsylvanian and Permian Periods. Carbon dioxide and helium are also produced in the province.

Reservoir rocks. Major production in the Paradox basin is from the Pennsylvanian Hermosa Group, Paradox Formation and the Mississippian Leadville Formation. Production from the Uncompahgre uplift is mostly from the Cretaceous Dakota Sandstone, fractured Mancos Shale, Cedar Mountain Sandstone, and Castle Gate Member of the Mesaverde Formation; from the Jurassic Salt Wash Member of the Morrison Formation and Entrada Sandstone; and from the Permian Coconino Sandstone. On the San Rafael Swell, production has been from the Upper Cretaceous Ferron Member of the Mancos Shale, the Jurassic Navajo Sandstone and the Triassic Moenkopi Limestone. Other reservoir rocks in the province include the Triassic Sinbad Limestone and Timpoweap Limestone, the Permian Kaibab Limestone and White Rim Sandstone, and the Devonian McCracken Sandstone.

Traps. Stratigraphic traps are common in the Paradox basin. These include biohermal carbonate mounds and porosity changes, and are more common in the southern portion of the basin. Salt anticlines and faulted anticlines are more common in the northern part of the basin. Sub-salt fault blocks are a major trapping mechanism. On the Uncompahgre uplift and San Rafael Swell, anticlines and porosity pinchouts are trapping mechanisms.

Source rocks. The source of hydrocarbons appears to be mostly from Pennsylvanian-age rocks, especially the black shales interbedded with salt in the Paradox Formation. The Cretaceous Mancos Shale and Frontier Formation are the probable source beds for much of the Mesozoic production.

Future exploration. This province is in an early stage of exploration. Other reservoir intervals in addition to the Pennsylvanian rocks need to be examined in the Paradox basin, especially the Ferron Sandstone Member of the Mancos Shale, and the Glen Canyon Group, the White Rim Sandstone, Kaibab and Coconino Formations. There are probably additional salt anticline traps and algal mounds as well as other structural traps and updip pinchouts to be discovered. Possible traps also lie beneath laccolithic intrusions in the region.

P-545, SAN JUAN MOUNTAINS, SAN LUIS BASIN, LAS VEGAS-RATON BASIN
AND SIERRA GRANDE UPLIFT
Generalized Stratigraphic Section

AGE	FORMATION	
	WEST	EAST
Cenozoic		
Oligocene		Farisita Cgl.
Eocene	Telluride-	Huerfano Fm.
	-Blanco Basin Fm.	Cuchara Fm.
Paleocene	Animas Fm.	Poison Canyon Fm.
		#Raton Fm.
Mesozoic		
Cretaceous		
Upper	Kirtland Sh.	#Vermejo Fm.
	#Fruitland Fm.	#Trinidad Ss.
	Pictured Cliffs Ss.	Pierre Sh.
		Niobrara Fm.
	Lewis Sh.	Smoky Hill Marl Mbr.
	Mesaverde Gp.	Ft. Hays Ls. Mbr.
		Benton Group
	Mancos Sh.	Carlile Sh.
		Codell Ss. Mbr.
		Greenhorn Ls.
	*Dakota Ss.	Graneros Sh.
Lower	Burro Canyon Fm.	*Dakota Ss.
		Purgatoire Fm.
Jurassic	Morrison Fm.	Morrison Fm.
	Brushy Basin Mbr.	Exeter Ss.
	Salt Wash-	
	-Ralston Creek Mbr.	
		Entrada Ss.
	Wanakah Fm.	
Triassic	Entrada Ss.	
	Chinle Fm.	Johnson Gap Fm.
Paleozoic		Dockum Group
Permian	Dolores-Santa Rosa Fm.	
	Bernal Fm.	Whitehorse Fm.
	Cutler Fm.	San Andres Ls.
		**Glorieta ("Lyons") Ss.
		Yeso Fm.
Pennsylvanian	#Rico Fm.	Sangre de Cristo Fm.
		#Magdalena Group
	Hermosa Fm.	Madera Fm.
Mississippian		Sandia Fm.
	Leadville Ls.	Meramac Group
	Terrero Fm.	
Devonian	Espiritu Santo Fm.	
Silurian		
Ordovician		
Cambrian		
	Ignacio Quartzite	Arbuckle Group
		Lamotte Ss.

* Currently producing ** Helium, nitrogen, CO₂, etc. # Potentially productive

P-550, PARADOX BASIN
Generalized Stratigraphic Section

AGE	FORMATION
Mesozoic	
Cretaceous	
Upper	*Mesaverde Gp. Cliff House Fm. Mencfee Fm. Point Lookout Fm.
	*Mancos Sh. Greenhorn Ls. Mbr. Graneros Sh. Mbr.
	*Dakota Fm.
Lower	*Burro Canyon Fm.
Jurassic	*Morrison Fm. Brushy Basin Mbr. Westwater Canyon Mbr. Recapture Mbr. Salt Wash Mbr.
	San Rafael Group Bluff Ss.-Junction Creek Ss. Summerville Fm. Curtis Fm. Entrada Fm. Carmel Fm.
Triassic	Glen Canyon Group Navajo Fm. Kayenta Fm. Wingate Fm.
	Chinle Fm. Moenkopi Fm.
Paleozoic	
Permian	Cutler Group Kaibab Fm. *White Rim Ss.-DeChelly Ss. Organ Rock Fm. Cedar Mesa Ss. Mbr. Halgaito Fm.-Elephant Canyon Fm.
	Pennsylvanian
	Hermosa Group *Honaker Trail Fm. Paradox Fm. Pinkerton Trail Fm. Molas Fm.
	Mississippian
	*Leadville Fm.
	Devonian
	Ouray Fm. Elbert Fm. Upper Elbert Mbr. *McCracken Ss. Mbr.
	Silurian
	missing
	Ordovician
	missing
	Cambrian
	Lynch Dolo. Muav Fm. Bright Angel Fm. Ignacio Quartzite Tapeats Ss.
	*Currently producing

No future productive reservoirs, not presently producing, are anticipated.

Accumulations in the Pennsylvanian biohermal mounds will probably be in the 1 to 25 Bcf range, while those in the Mississippian structural traps should be in the 20 to 300 Bcf range. Accumulations in the Permian Cutler and Pennsylvanian Honaker Trail formations should be in the 5 to 50 Bcf range.

P-555, SAN JUAN BASIN

The San Juan basin is one of the major gas provinces of the United States. It is bounded on the south by the Zuni uplift, on the east by the Defiance uplift, on the north by the San Juan uplift and on the east by the Nacimiento uplift. This structural basin covers 15,000 to 20,000 square miles and contains up to 15,000 feet of sedimentary rocks.

In the neighborhood of 20,000 wells have been drilled in the basin, of which approximately 17,000 are gas wells. Very little exploration drilling below the Cretaceous has been done outside of the Barker Dome Penn-Paradox and virtually nothing has been completed below 15,000 feet.

Probable resources are anticipated to be associated with established fields and will be discovered by extension of those fields. Due to a lack of aggressive "wildcatting" throughout the basin, the Possible category is separated from the Probable category. In general, speculative resources have not been considered in the San Juan basin.

Reservoir rocks. Production in the basin is mostly from Cretaceous sandstones. Upper Cretaceous reservoir rocks include the Pictured Cliffs Sandstone, the Fruitland Formation, the Chacra Sandstone, the Mesaverde Group (Cliff House and Point Lookout Members) and the Gallup Sandstone. With fracturing, some oil has been produced from the Mancos Shale. The Dakota Group is the dominant Lower Cretaceous reservoir in the basin. There is limited production from the Jurassic Entrada Sandstone and Morrison Formation. The Pennsylvanian Hermosa Formation produces oil, natural gas and helium along the western flank of the basin. Helium is found in the Devonian Ouray Limestone.

Traps. Stratigraphic trapping dominates in the basin. The specific trapping conditions include sandstone lenses, channels and bars and are influenced by differential compaction related to ancient topographic highs. The sedimentary rocks in the area are largely underpressured. Hydrodynamic traps have been recognized in the Gallup and Entrada Sandstones. Anticlinal traps are confined to the southwestern flank of the basin. Hydrodynamic conditions together with low permeability of reservoir rocks and the mechanism of gas generation are the main factors which have resulted in the formation of one giant gas field in the Cretaceous rocks of the central portion of the basin.

Potential source rocks. The Upper Cretaceous Mancos Shale and the Menefee Member of the Mesaverde Formation are the most likely sources for hydrocarbons found in the Upper Cretaceous reservoirs. The upper Jurassic Todilto Formation may have been a source bed for the Dakota Group and for the Entrada Sandstone. The Hermosa Formation is another likely source bed, as are the coal beds in the Fruitland Formation.

Producing trends. The Hogback monocline on the northwestern flank of the basin is a striking structural feature with several producing fields. Anticlines are confined to the rims of the basin and no folding has been detected in the central portion of the basin. Upper Cretaceous rocks in the central portion constitute basically one giant gas field, the Basin Dakota field, with a diameter of 100 miles and covering an area of over one million acres, in which production occurs at depths shallower than 8,000 feet. Production in the Pictured Cliffs Sandstone is from elongate, northwest-trending sandstone stringers encased in shales.

Future exploration. Potential reservoir rocks below the Dakota Group include the Pennsylvanian section and the Jurassic. The Basin Dakota field may extend into Sandoval County. The southern and eastern flanks of the basin warrant further exploration.

Coalbed methane. The coal beds in the basin are contained within an Upper Cretaceous near-shore marine and deltaic-transitional sequence that is as much as 8,000 feet in thickness. Coal beds occur in this sequence in the Dakota Sandstone, Mesaverde Group, and Fruitland Formation. The multiple seams of coal in the Fruitland Formation, each of which can attain thicknesses of as much as 40 feet, constitute the most

attractive coalbed methane resource target in the San Juan Basin. The Fruitland up to now has been the chief interval targeted for coalbed methane development in the basin. However, some operators currently are showing increasing interest in exploiting gas in coals in the deeper Menefee Formation (of the Mesaverde Group). The northern part of the basin contains the largest coalbed methane resource potential and is characterized by the greatest thickness of net Fruitland coal (as much as 80 feet), the highest heat flow and resulting high coal rank (up to low-volatile bituminous), and maximum in-place gas contents (200 to 450-plus cubic feet/ton of coal).

The development of coalbed methane in the San Juan Basin is progressing at a rapid pace, with several hundred new wells slated for completion within the next year or two. Most of these are expected to be drilled by Amoco Production Co. and Meridian Oil Co. To date, more than 450 wells have been completed in Fruitland coals in the basin, with cumulative production in excess of 17 Bcf gas. Typically, initial production rates vary from about 50 to 500 or more Mcf/day, usually with some water. However, Meridian Oil has completed several wells in Rio Arriba County, New Mexico, flowing at rates between 6 and 11 MMcf/day; these appear to be the most prolific coalbed methane wells in the world. Total depths of coalbed methane wells in the basin range from approximately 1,200 to 4,100 feet, with the majority believed to have been completed at depths between about 2,000 and 3,500 feet.

It is estimated that the in-place methane resource in the Fruitland coal beds in the San Juan Basin totals approximately 50 Tcf; most of this resource occurs in the northern part of the basin. Studies currently are under way to assess the coalbed methane potential of the Menefee coals in the basin. The Fruitland coals in the San Juan Basin contain at least 27 Tcf of recoverable coalbed methane resources.

P-555, SAN JUAN BASIN
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Eocene	San Jose Fm.
Paleocene	Nacimiento Fm.
	Ojo Alamo Ss.
Mesozoic	
Cretaceous	
Upper	Kirtland Sh. Upper Shale Mbr. Farmington Ss. Mbr. Lower Shale Mbr. *Fruitland Fm. *Pictured Cliffs Ss. Lewis Sh. *Mesaverde Gp. Cliff House Ss. Menefee Fm. Point Lookout Ss. Mancos Sh. Upper Shale-Gallup Ss. Mbr. Sanostee Mbr. Greenhorn Ls. Graneros Sh.
Lower	*Dakota Ss. Burro Canyon Fm.
Jurassic	*Morrison Fm. Brushy Basin Mbr. Westwater Canyon Mbr. Recapture Mbr. Salt Wash Mbr. Summerville Fm. Todilto Ls. *Entrada Ss. Carmel Fm. Triassic
	#Wingate Ss. Chinle Fm. #Shinarump Cgl. Mbr. Moenkopi Fm.
Paleozoic	
Permian	DeChelly Ss. #Cutler Fm.
Pennsylvanian	*Hermosa Group Honaker Trail Fm. Paradox Fm. Pinkerton Trail Fm. Molas Fm.
Mississippian	Leadville Ls.
Devonian	** Ouray Ls. Elbert Fm. Upper Elbert Mbr. McCracken Ss. Aneth Fm.
Silurian	missing
Ordovician	missing
Cambrian	Ignacio Quartzite

* Currently producing **Helium #Potentially productive

P-560, SOUTHERN BASIN AND RANGE PROVINCE

This province covers southern Arizona and southwestern New Mexico. Production of natural gas or oil has been established in Otero County, New Mexico, but is currently shut in. Carbon dioxide has been produced from the Estancia field in Tarrant County, New Mexico. This area is considered a frontier region for petroleum exploration whose potential has not yet been determined.

Southern Arizona is a region of Precambrian rocks, lava flows and alluvial deposits. It has been postulated that the Western Thrust Belt extends from southernmost Nevada across southern Arizona, but this has not been confirmed by the results of limited drilling. If the Thrust Belt does exist in this region, then the potential for future production would be greatly increased. Additionally, discoveries of natural gas in Mexico, south of southwestern Arizona, raise some possibility for the establishment of production in westernmost Arizona. The Pedregosa basin of southeastern Arizona and southwestern New Mexico contains over 14,500 feet of sedimentary rocks and, thus, has some potential for production.

Central and southern New Mexico contains five sedimentary basins and the Lucero shelf. Sedimentary rocks representing all periods of the Paleozoic Era are present together with Jurassic and Cretaceous sedimentary rocks. Central New Mexico contains a thick Miocene-Pliocene sequence of continental sedimentary rocks and volcanics. The Tularosa (Orogrande) and Jornada del Muerto basins contain over 7,000 feet of sedimentary rocks. The Tularosa basin contains prospective Pennsylvanian biohermal limestones.

Reservoir rocks. Potential reservoir rocks in central New Mexico include the Cretaceous Dakota Formation and Gallup Sandstone; the Jurassic Entrada Sandstone; the Permian Glorieta Sandstone and San Andres Limestone; the Pennsylvanian-Permian Sangre de Cristo Formation; and the Pennsylvanian Hermosa Formation and Madera Limestone. South-central New Mexico reservoirs include the Pennsylvanian Magdalena Group; the Mississippian Lake Valley Formation; the Silurian Fusselman Formation; and the Ordovician El Paso and Montoya Formations as well as undifferentiated Cretaceous, Permian and Pennsylvanian rocks.

Potential reservoirs in the Pedregosa basin range in age from Cambrian to Early Cretaceous and include the Lower Cretaceous Mojado and the upper Bisbee Group; the Permian Colina, Epitaph, Concha and Rainvalley Formations; the Pennsylvanian Horquilla and Earp Formations; the Mississippian Paradise and Escabrosa Formations; the Devonian Martin Formation; the Silurian Fusselman Formation; the Ordovician El Paso and Montoya formations; and the Cambro-Ordovician Bliss Sandstone and Abrigo Formation.

Traps. Potential traps are both structural and stratigraphic. Anticlinal and faulted anticlinal traps are present. Stratigraphic traps include bioherms, sandstone channels and lenses, carbonate-evaporite sequences and carbonate-red bed sequences. Thrust faulting, shear zones and block faulting form potential traps in southern Arizona.

Potential source rocks. Potential source rocks in central New Mexico are the Cretaceous Mancos Shale and Colorado Group, Jurassic Todilto Limestone, Permian San Andres Limestone, and Pennsylvanian Madera Formation. In south-central New Mexico, the prospective source rocks are the Cretaceous Mancos Shale, Permian Hueco-Colina Formations, Pennsylvanian Gray Mesa Formation, Mississippian Lake Valley-Escabrosa Limestone and Devonian Percha Formation. In southern Arizona and southwestern New Mexico, possible source rocks include the Permian Colina, Epitaph, Concha, Scherrer, and Rainvalley Formations; Pennsylvanian Horquilla Formation; Mississippian Paradise Formation; and Devonian Percha Formation.

P-565, PLATEAU PROVINCE AND BLACK MESA BASIN

This province covers northern Arizona and part of southern Utah. The province includes the Colorado Plateau, the Black Mesa basin and the Defiance uplift. Production in the province is presently confined to the Defiance uplift. The Colorado Plateau consists of a thick series of sedimentary rocks which have undergone relatively little deformation since their deposition. The section does not contain favorable potential

source rocks and there are relatively few potential traps, so the Colorado Plateau has little or no potential for future natural gas production. The Black Mesa basin is a structural downwarp instead of a depositional sedimentary basin and also has little or no potential for future natural gas production.

Reservoir rocks. Current production comes from rocks ranging in age from Devonian to Cretaceous. The reservoir formations include Cretaceous sandstones; the Permian Coconino Sandstone; the Pennsylvanian Paradox and Naco Formations; the Mississippian Leadville Limestone; and the Devonian Aneth and McCracken Formations. All intervals produce both oil and natural gas. Helium is also produced from both the Coconino Sandstone and the Devonian reservoirs.

Traps. Biohermal limestones are common in the Aneth Formation. Variable porosity and permeability is a common stratigraphic trap. Both anticlines and faulted anticlines are prospective targets. Production has also been developed in units adjacent to a Tertiary sill.

Potential source rocks. The probable source beds for the province are carbonate rocks, including the Pennsylvanian Paradox and Naco Formations and the Devonian Aneth and Martin Formations.

Future exploration. Much of the province apparently has little potential for natural gas production. The Defiance uplift, however, has been sparsely explored and, undoubtedly, contains more stratigraphic traps. Mesozoic intervals have been largely ignored and contain potential reservoirs.

P-560, SOUTHERN BASIN AND RANGE PROVINCE
Generalized Stratigraphic Section

AGE	FORMATION	
	SOUTH & WEST. ARIZONA	SOUTH & WEST. NEW MEXICO
Cenozoic		
Miocene	various volcanics	Santa Fe Group Popotosa Fm. volcanics
Oligocene	various volcanics	Spears Fm.
Eocene	various volcanics	Baca Fm.
Paleocene	intrusives and volcanics	
Mesozoic		
Cretaceous		
Upper	intrusives and volcanics	Mesaverde Fm. (West) Crevasse Canyon Fm. #Gallego Mbr.(Gallup) Ss. Mancos Sh. D-Cross Sh. Tongue Tres Hermanos Mbr. Lower Tongue #Sarten-Dakota Ss.
Lower	Livingston Hills Fm.(West) #Bisbee Group (South) #Mojado Fm. (S.E.) U-Bar Fm. (S.E.) Hell-to-Finish Fm (S.E.) Bathtub Fm.South) Temporal Fm. (South) McCoy Mountains Fm. (West) various intrusives and volcanics	
Jurassic		Chinle Fm.-Dockum Group
Triassic		
Paleozoic		
Permian	Kaibab Ls.(West) Naco Group (South) #Rainvalley Fm. #Concha Ls. Coconino Ss. (West) Scherrer Fm. (South) Concha (S.E.) Supai Fm. (west) #Epitaph Dolo. #Colina Ls.	#San Andres Fm. #Glorieta Ss.
Pennsylvanian		Yeso Fm. Abo Fm. Panther Seep Fm. (South)- #Madera Ls.-Magdalena Group #Lead Camp Ls. Sandia Fm. Helms Fm.
Mississippian	#Horquilla Fm. Black Prince Ls. (South) #Paradise Fm. (S.E.) #Escarbosa Ls.	#Rancheria Fm (South) Las Cruces Fm. (South) #Lake Vailey Fm. (South)-Kelly Ls. Caballero Fm (South)- Caloso Fm.
Devonian	Martin Fm.-Percha Sh.	Percha Sh.
Silurian		#Fusselman Dolo.
Ordovician	#Montoya Fm. (S.E.) #El Paso Fm. (S.E.) #Bliss Fm. (S.E.) #Abrigo Fm.	#Montoya Fm. #El Paso Group #Bliss Fm.
Cambrian	Bolsa Quartzite	

#Potentially productive

P-565, PLATEAU PROVINCE AND BLACK MESA BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	PLATEAU PROVINCE	BLACK MESA BASIN
Cenozoic		
Miocene	Brian Head Fm.	
Eocene		
Paleocene	Wasatch Fm.	
Mesozoic		
Cretaceous		
Upper	Kaiparowits Fm.	Mesa Verde Group
		Yale Point Fm.
		Wepo Fm.
		Toreva Fm.
	Wahweap Ss.	Mancos Sh.
	Straight Cliffs Ss.	#Dakota Fm.
	Tropic Sh.	
	#Dakota Ss.	
Jurassic	Morrison Fm.	Morrison Fm.
	San Rafael Group	San Rafael Group
	Cow Springs Ss.	Cow Springs Fm.
	Entrada Ss.	Entrada Ss.
	Carmel Fm.	Carmel Fm.
	Glen Canyon Group	Glen Canyon Group
	Navajo Ss.	Navajo Ss.
	Kayenta Fm.	Kayenta Fm.
	Moenave Fm.	Moenave Fm.
Triassic	Chinle Fm.	Chinle Fm.
	Shinarump Cgl. Mbr.	Shinarump Cgl. Mbr.
	Moenkopi Fm.	Moenkopi Fm.
Paleozoic		
Permian	Kaibab Ls.	Kaibab Fm.
	Toroweap Fm.	
	Coconino Ss.	**Coconino-DeChelly Ss.
		Cutler Fr.
	Hermit Sh.	Organ Rock Sh.
	Supai Fm.	Cedar Mesa Mbr.
		Halgaito Mbr.
Permo-Penn.	Supai Fm.	
Pennsylvanian		*Hermosa Group
	Molas Fm.	Molas Fm.
Mississippian	#Redwall Ls.	*Redwall Ls.
Devonian	#Temple Butte Ls.	Ouray Fm.
		*Elbert fm.
		*Aneth Fm.
Cambrian		Lynch Dolo.
	Tonto Group	Tonto Group
	Muav Ls.	Muav Ls.
	Bright Angel Sh.	Bright Angel Sh.
	#Tapeats Ss.	#Tapeats Ss.
Precambrian		
Proterozoic	Grand Canyon "Supergroup"	

*Currently producing #Potentially productive
**Inert gas, helium, etc.

P-570, SWEETGRASS ARCH AND CENTRAL MONTANA

This region covers the central portion of Montana. It contains a thick series of sedimentary rocks of Mesozoic and Paleozoic age, including both clastic and carbonate rocks. Numerous domes, arches, and young intrusive mountain complexes dot the province. Both associated/dissolved and non-associated gas are produced in this region.

Reservoir rocks. Numerous sandstone reservoir rocks of Cretaceous age include the Judith River and Eagle Members of the Pierre Shale, the Bow Island Member of the Blackleaf Formation, Frontier Formation, Cat Creek, Viking, Moulton, Sunburst, Lakota, and Cutbank Sandstones. On the Sweetgrass arch, the Jurassic Swift and Sawtooth Formations of the Ellis Group are productive. Paleozoic units of interest are the Pennsylvanian Amsden Group and Tyler Formation; Mississippian Madison Group; and Devonian Nisku (Birdbear) Formation.

Traps. Anticlines and domes form traps for all stratigraphic intervals throughout the region. Faults are numerous due to various tectonic events in the area and provide traps for many units. In all Cretaceous units and in the Tyler Formation, traps occur in sandstone channels and lenses. Porosity variations occur in all intervals. In the Madison, buried topographic traps can be found. At various intervals, angular unconformities are the trapping mechanism. Hydrodynamic tilting of oil/water and gas/water contacts occurs in the south-central portion of the province.

Potential source rocks. Many Jurassic and Cretaceous units are potential source rocks. These are the Montana Group, Colorado Group, Inyan Kara Group, and Rierdon Formation. Paleozoic sources are probably the Tyler; Mississippian Heath and Lodgepole Formations; and Devonian-Mississippian Cottonwood Canyon and Bakken Formations.

P-575, MONTANA FOLDED BELT

This region includes the northern projection of the Wyoming-Utah-Idaho Thrust belt. The configuration of the region was formed during the Laramide Orogeny in late Cretaceous and early Tertiary time. This deformation involving both Paleozoic and Mesozoic rocks, proceeded from west to east and progressively older sedimentary rocks are involved to the west where more faulting has occurred. Major thrust faults, and imbricating minor thrusts, form a series of complexly folded and faulted thrust packages. Folding is common in all intervals. In various portions of the province, several older, northeast-trending, fault blocks affect the thickness of the strata.

Southwestern Montana underwent deformation of a different nature starting with major vulcanism during Campanian time. This was followed by emplacement of the Boulder batholith in latest Cretaceous time. The western portion of the province is made up of mountain belts.

Potential reservoir rocks. The Mississippian Madison Group is presently the only productive interval in this region. Other prospective units are Paleocene sandstones; the Cretaceous Fox Hills Sandstone, Eagle Sandstone Member of the Pierre Shale, Cloverly Formation, Cat Creek Sandstone, Lakota Formation, and Cutbank Sandstone Member of the Kootenai Formation. Possible Paleozoic reservoirs are the Pennsylvanian Quadrant Formation and Shedhorn Sandstone; and the Devonian Three Forks and Jefferson Formations. It is also possible that fractured Proterozoic Belt Supergroup strata will prove productive.

Traps. Major trapping mechanisms in the area are formed by thrust faults, folds and faulted folds. Traps occur in sandstone bars and channels within the Cretaceous and Tertiary units. Facies changes in Paleozoic carbonate rocks are a possible trapping mechanism.

P-570, SWEETGRASS ARCH AND CENTRAL MONTANA
Generalized Stratigraphic Section

AGE	FORMATION		
	WEST FLANK	EAST FLANK	CENT. MONTANA
Cenozoic			
Paleocene	Tert. sed. rocks Willow Creek Fm.	Tert. sed. rocks	Ft. Union Fm
Mesozoic			
Cretaceous			
Upper	St. Mary River Fm. Horse Thief Ss. Two Medicine Fm. *Virgelle-Eagle Ss. Telegraph Creek Fm. Marias River Fm. Kevin Sh. Mbr. Ferdig Sh. Mbr. Cone Calc. Mbr. Floweree Mbr.	Hell Creek Fm. Fox Hills Ss. Bearpaw Shale Judith River Fm. Claggett Sh. *Virgelle-Eagle Ss. Telegraph Creek Fm. Niobrara Fm. Carlile Fm. Greenhorn Fm.	Hell Creek Fm. Fox Hills Ss. Bearpaw Shale Judith River Fm. Claggett Sh. *Eagle Ss. Telegraph Creek Fm. Niobrara Fm. Carlile Fm. Greenhorn Fm. Belle Fourche Sh.
Lower	*Blackleaf Fm. Bootlegger Mbr. Vaughan Mbr. Taft Hill Mbr. Flood Mbr. Kootenai Fm. *Morrison Fm. *Swift Fm. Rierdon Fm. *Sawtooth Fm.	Mowry Sh. *Bow Island Ss. *Dakota Ss. Kootenai Fm. *Morrison Fm. *Swift Fm. Rierdon Fm. *Piper Fm.	Mowry Sh. Muddy Ss. Skull Creek Sh. Dakota Ss. Kootenai Fm. *Morrison Fm. *Swift Fm. Rierdon Fm. *Piper Fm.
Jurassic			
Paleozoic			
Pennsylvanian			Tensleep Fm. *Amsden Group
Mississippian	Castle Reef Dolo. *Mission Canyon Ls. Lodgepole Ls.	Castle Reef Dolo. *Mission Canyon Ls. Lodgepole Ls.	*Big Snowy Group Charles Fm. *Mission Canyon Ls. Lodgepole Ls.
Devonian	Exshaw Fm. Three Fks-Potlach Fm. #Jefferson Group Souris River Fm.	Exshaw Fm. Three Forks Fm. #Jefferson Group Souris River Fm.	#Jeff.-Duperow Gp.
Silurian			
Ordovician			Red River Fm.
Cambrian	Devils Glen Dolo. Switchback Sh. Steamboat Ls. Pagoda Ls. Dearborn Ls. Damnation Ls. Gordon Sh. #Flathead Ss.	Upper Emerson Fm. Pentagon Sh. #Flathead Ss.	Snowy Range Fm. Pilgrim Ls. Park Sh. Meagher Ls. Wolsey Fm. #Flathead Ss.
Precambrian	Belt Supergroup		Belt Supergroup

* Currently producing # Potentially productive

P-575, MONTANA FOLDED BELT
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	Various volcanics & conglomerates
Mesozoic	
Cretaceous	
Upper	Montana Group Willow Creek Fm. St. Mary River Fm. Two Medicine Fm. #Virgelle Fm. Telegraph Creek Fm. Colorado Group Marias River Sh. Blackleaf Fm. Vaughan-Dunkleburg Mbr. Taft Hill Mbr. Flood Mbr.
Lower	
Jurassic	#Kootenai Fm. Morrison Fm. Ellis Group #Swift Fm. Rierdon Fm. Sawtooth Fm.
Triassic	Thaynes Fm. Woodside Fm. Dinwoody Fm.
Paleozoic	
Permian	Shedhorn Ss. Phosphoria Fm. Park City Fm.
Pennsylvanian	#Quadrant Fm. Amsden Fm.
Mississippian	Big Snowy Group *Madison Group Mission Canyon Ls. Lodgepole Ls.
Devonian	Three Forks Fm. #Jefferson Formation Maywood Fm. Beartooth Butte Fm.
Ordovician	Bighorn Dolo.
Cambrian	Red Lion-Snowy Range Fm. Haskmark Dolo. Silver Hill-Wolsey Fm. Flathead Ss.
Proterozoic	Mission Group Helena Dolo. Empire Fm. Spokane Fm. Prichard Fm.

* Currently producing # Potentially productive

Potential source rocks. Possible source rocks include Paleocene shales; the Cretaceous Montana and Colorado Groups; the Triassic Thaynes Formation; the Pennsylvanian Phosphoria Formation; and the Devonian-Mississippian Exshaw and Sappington Member of the Three Forks Formation. Possible Precambrian source beds include the black shale strata in the Belt Supergroup of Middle Proterozoic age.

P-580, SNAKE RIVER BASIN

The Snake River downwarp is an arcuate basin whose borders lie on either side of the Snake River and roughly parallel the river. The basin lies between the overthrust fold belts of east-central and southeast Idaho and extends to the southwestern edge of Idaho, as far as, but not including, the Hells Canyon area.

The rock section is composed of numerous extrusive volcanic flows and air-fall material interbedded with fluvial and lacustrine clastic deposits which are more prominent in the southwestern area. Some black shales and a few coal beds are included in the section.

Numerous gas shows, ranging in quality from 750 to 1,400 Btu's per cubic foot have been found through seeps and in wells. Juvenile bitumens, apparently in place, have also been noted. Reservoir rocks and apparent source rocks have been identified. Trapping mechanisms pose a question. Drilling has been sparse to date and no commercial discoveries have been made, but there is continued industry interest spurred by shows. The potential for commercial natural gas accumulations is difficult to define. The exploration risk is high, but there are enough favorable indicators to hold out promise for the basin.

P-590, WYOMING-UTAH-IDAHO THRUST BELT

This area is made up of severely deformed Paleozoic and Mesozoic sedimentary rocks, mostly of marine origin. Deformation occurred during the Laramide Orogeny in Cretaceous and early Tertiary time. The region is composed of a complex series of thrust sheets with anastomosing smaller thrust and later normal faults, making exploration difficult. Styles of deformation vary through the belt. In most areas, the rocks are tightly folded as well as faulted. In other areas, Paleozoic rocks are severely faulted, whereas overlying Mesozoic sedimentary rocks are both folded and faulted. The stacked sediment package is over 49,000 feet thick in the western portion of the province and 14,000 feet thick in the east. Production is presently confined to Wyoming and the area of Utah adjacent to the southwestern corner of Wyoming (Fossil basin). Oil, associated/dissolved gas, non-associated gas and condensate are produced. Non-associated gas from Paleozoic carbonate reservoirs is sour. The Idaho portion of the province has produced shows and continues to be an exploration target.

Reservoir rocks. Sixteen units ranging in age from Ordovician to Late Cretaceous are presently producing in this province. The Mississippian Madison Limestone, Triassic-Jurassic Nugget Sandstone and Permian-Pennsylvanian Weber Sandstone and Ordovician Bighorn Dolomite are major targets in this region. Other reservoirs include the Upper Cretaceous Frontier Formation; Jurassic Stump Sandstone and Twin Creek Limestone; Triassic Thaynes Limestone, Woodside Formation and Dinwoody Formation; Permian Phosphoria Formation; and Devonian Darby Formation.

Traps. Structural trapping affects all stratigraphic intervals and includes folded and thrust anticlines. Potential stratigraphic traps include carbonate mounds in the Thaynes Limestone, changes in carbonate facies, and pinchouts in Upper and Lower Cretaceous sandstones.

Potential source rocks. The main source of hydrocarbons is Cretaceous marine shales. Other possible sources include the Phosphoria, Thaynes, and Devonian Three Forks Formations.

P-590, WYOMING-UTAH-IDAHO THRUST BELT
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Miocene	Salt Lake Fm.
Eocene	Norwood Tuff
	Fowkes Fm.
	Green River Fm.
	Wasatch Fm.
Paleocene	Evanston-Sublette Range Fm.
Mesozoic	
Cretaceous	Adaville Fm.
Upper	#Hilliard Fm.-Shurtliff Ss.
	#Frontier Fm.
Lower	#Aspen Sh.
	Sage Jct. Fm.
	Quealy Fm.
	#Cokeville-Wayan Fm.
	*Bear River Fm.
	Thomas Fork Fm.
	Smiths Fm.
	Gannett Group
Jurassic	*Stump Ss.
	Preuss Ss.
	*Twin Creek Ls.
	*Nugget Ss.
Triassic	*Ankareh Fm.
	*Thaynes Ls.
	Woodside Fm.
	*Dinwoody Fm.
Paleozoic	
Permian	*Phosphoria Fm.
Pennsylvanian	Wells Fm.-Weber Ss.
Penn.-Miss.	Amsden Fm.
Mississippian	Madison Ls.
	*Mission Canyon Ls. Mbr.
	*Lodgepole Ls. Mbr.
Devonian	*Darby Fm.
Silurian	Laketown Dolo.
Ordovician	*Bighorn Dolo.
Cambrian	Gallatin Ls.
	Gros Ventre Fm.
	Flathead Ss.

*Currently producing #Potentially productive (subthrust-footwall)

Table 11. Estimated resources of natural gas for provinces of the Rocky Mountain Area, December 1988
(billion cubic feet)

PROVINCE	ONSHORE		OFFSHORE	PROBABLE		POSSIBLE		SPECULATIVE				
	depth		water depth	Min.	M. likely	Max.	Min.	M. likely	Max.	Min.	M. likely	Max.
P-500, Williston basin	0-15,000'			300	1,000	1,500	400	500	600	*	300	500
	15-30,000'									*	*	100
P-510, Powder River basin	0-15,000'			700	1,100	1,500	1,500	2,200	2,700	300	500	700
	15-30,000'									500	1,000	2,000
P-515, Big Horn basin	0-15,000'			400	550	1,000	400	550	1,000	*	*	*
	15-30,000'			100	150	450	500	650	1,300	*	400	700
P-520, Wind River basin	0-15,000'			600	1,250	1,800	1,800	3,550	5,400	*	*	*
	15-30,000'			2,950	3,400	4,250	2,500	3,100	5,100	*	400	700
P-530, Greater Green River basin	0-15,000'			7,900	9,700	12,000	7,200	12,800	20,300	300	3,400	7,000
	15-30,000'			4,500	5,000	5,500	11,400	15,600	20,600	100	2,500	7,500
P-535, Denver basin, Chadron arch and Las Animas arch	0-15,000'			1,700	3,000	5,000	900	2,100	4,600	*	*	150
	15-30,000'									*	*	*
P-540, Uinta/Piceance basins, Park and Eagle basins	0-15,000'			5,000	7,100	10,200	2,800	4,000	5,500	200	400	2,300
	15-30,000'			200	500	1,500	100	200	800	100	300	2,100
P-545, San Juan Mountains, San Luis/Raton basins, etc.	0-15,000'						100	400	1,000	*	700	1,400
	15-30,000'									*	300	600
P-550, Paradox basin	0-15,000'			50	150	200	500	900	3,000	100	300	700
	15-30,000'									*	*	*
P-555, San Juan basin	0-15,000'			1,000	1,500	2,500	300	500	1,000	*	*	*
	15-30,000'									*	*	*
P-560, Southern Basin and Range province	0-15,000'						*	1,400	5,600	*	*	50
	15-30,000'									*	*	*

*Negligible quantity of natural gas estimated.

Table 11 (continued). Estimated resources of natural gas for provinces of the Rocky Mountain Area, December 1988
(billion cubic feet)

PROVINCE	ONSHORE depth	OFFSHORE water depth	PROBABLE			POSSIBLE			SPECULATIVE		
			Min.	M. likely	Max.	Min.	M. likely	Max.	Min.	M. likely	Max.
P-565, Plateau province, Black Mesa basin	0-15,000'		*	*	50	*	50	100	50	250	500
	15-30,000'								*	*	*
P-570, Sweetgrass arch	0-15,000'		1,800	2,300	3,200	1,400	1,900	2,400	800	1,100	1,350
	15-30,000'								*	*	*
P-575, Montana Folded Belt	0-15,000'		*	*	100	*	1,000	2,000	*	2,500	3,500
	15-30,000'								*	*	*
P-580, Snake River basin	0-15,000'								100	200	300
	15-30,000'								*	*	*
P-590, Wyoming-Utah-Idaho Thrust Belt	0-15,000'		1,000	2,300	3,400	500	2,400	6,000	1,300	4,000	10,000
	15-30,000'		3,000	5,000	8,000	800	1,200	3,000	1,000	2,200	4,000
TOTAL, onshore	0-15,000'			29,950			34,250			13,650	
TOTAL, onshore, all depths	15-30,000'			14,050			20,750			7,100	
GRAND TOTAL FOR AREA				44,000			55,000			20,750	

*Negligible quantity of natural gas estimated.



PACIFIC AREA

During 1987 and 1988, exploration activity within the Pacific region continued at low levels despite a very modest improvement in some areas. The Sacramento Valley still accounts for the majority of gas exploratory drilling in the Pacific region. The Sacramento Valley experienced better exploratory successes during 1988 than there have been in the last four years. Over the past two years, there have been numerous discoveries of new fields, new pools and extensions. Although sizeable amounts of gas became proven reserves, the resource estimates for the area remain unchanged as a result of increased optimism.

Significant exploration achievements in the Sacramento Valley for 1987-88 include:

1. Continued extensions of F Zone production throughout the northern portion of the valley, particularly at Grimes and surrounding gas fields.
2. The Cretaceous-Winter Sands new-field discovery at Hog Slough in San Joaquin County shows promising potential.
3. The discovery of the Knights Landing gas field in the Starkey Sand in early 1988 has resulted in seven excellent completions during the year. A new pool was also discovered in the Starkey Sand at Cache Creek North.
4. Several new pool discoveries were found in the traps formed against the Meganos Gorge Fill in Contra Costa County.
5. Continued successful developments at Lindsey Slough and Denver Creek resulted in several extensions and new pools in the southern Sacramento Valley.

Exploratory drilling in the San Joaquin Valley was dominated by oil plays. Activity continued along two major geological trends, namely, the Stevens Sand in the southern end of the Valley and field extensions along the western portion of the region. Several new fields and new pools, in addition to a number of extensions, were discovered in the last two years. The discovery of the Aqueduct and Pioneer Canal oil fields completed in the Stevens Sand are particularly noteworthy. In Fresno County, the two oil fields were

discovered in the Miocene Zilch. There was considerable development of the Landslide Field which was discovered in 1985. The record-breaking well at Elk Hills in Kern County reached a total depth of 24,426 feet. The deeper horizons showed little promise of commercial production. The results of this well coupled with other considerations led to a reduction in resource estimates below 15,000 feet.

Gas production in the San Joaquin Valley is predominantly associated/dissolved gas. The estimates of potential gas resources are in line with the potential oil discoveries.

Activities in the California Coastal Basins declined further from the already depressed level of 1986. A new gas field discovery near the city of Hawthorne is the only development of significance in the area.

Drilling around the Mist Gas Field resulted in one new gas pool discovery and a successful extension. The Mist remains the only producing field in Oregon.

Several exploratory wells were drilled in the state of Washington. Although no successful discoveries have been reported, the industry's renewed interest in this area is particularly significant.

Exploratory drilling in the Pacific Offshore has been rather limited and basically unsuccessful for over four years. The resource base estimates were updated to reflect the normal progression as gas becomes proven.

P-600, OREGON-WASHINGTON COASTAL BASINS, OKANOGAN PROVINCE

This province presently has one productive field, Mist Field in Clatsop County, Oregon. Potential in the region is basically confined to the coastal region. The coastal region is composed largely of Tertiary rocks (both marine and continental) with some interbedded lava flows and is covered in places with glacial drift.

The Olympic Mountains are mostly a metamorphic complex with some lava flows. The Okanogan Highlands of northern Washington are a combination of intrusive and extrusive igneous rocks with metamorphosed regions. Historically there have been two other fields in the province: Ocean City and Bellingham. Ocean City in Grays Harbor County, Washington, produced approximately 12,500 barrels in four years from a fractured Oligocene sandstone. The Bellingham gas field in Whatcom County, Washington, produced local amounts of Tertiary gas from sandstone lenses in glacial deposits.

Reservoir rocks. Present production is from the Eocene Cowlitz Formation. Potential reservoir rocks are the Miocene-Pliocene Quinault Formation, the Miocene Astoria Formation, the Miocene-Oligocene Yaquina Sandstone, and the Eocene Coaledo Formation.

Traps. The main traps in the area occur in sandstone lenses. Unconformity truncations affect Pliocene and late Eocene rocks. Shale diapirs with accompanying onlaps and faults form potential traps in Miocene and Pliocene rocks.

Source rocks. Potential source rocks in this area are the Miocene Nye Shale, the Oligocene Alsea Formation and the Eocene Coaledo and Yamhill Formations.

Coalbed methane. A resource of 3.6 to 24.0 Tcf of in-place coalbed methane is estimated for the coals of the Western Washington coal basin. No estimate has been made of the recoverable resource.

P-610, EASTERN COLUMBIA BASIN

This province has very little natural gas potential. Most of the region is covered with thick plateau basalts. The Cascade Mountains, a series of volcanoes, are also included in this region. Historically there has been one gas field in this province, Rattlesnake Hills. Production was from vesicular basalts. The trap was a faulted anticline with thin shales acting as the seal. Total production was one billion cubic feet of gas. The source rock is unknown. There is some possibility of production from reservoir rocks and source rocks lying below the thinner portions of the lava flows.

P-620, GREAT BASIN, SIERRA NEVADA, KLAMATH MOUNTAINS AND SOUTHERN OREGON

The region contains a thick Paleozoic section with lesser amounts of Mesozoic and Tertiary rocks. The Great Basin is composed of numerous horst and graben blocks which are internally folded and faulted. This complicates the stratigraphy and makes exploration more difficult. Present oil production is limited to five fields in Nevada, four of these in Railroad Valley. One of the wells in Railroad Valley has the highest rate of oil production of any well in the lower 48 states. There is also limited production in the Klamath Mountains. The province is a region of major mineral exploration also.

Reservoir rocks. Past production has been from freshwater limestones and tuffs of the Eocene Sheep Pass Formation. Other potential reservoirs are the Permian Meade Park Shale Member of the Phosphoria Formation, the Mississippian Deseret Limestone and Chainman Shale and the Devonian Pilot Shale. Other Mesozoic and Paleozoic sandstones and carbonate rocks may be potential reservoirs.

P-620, GREAT BASIN, SIERRA NEVADA, KLAMATH MTNS.-SOUTHERN OREGON
Generalized Stratigraphic Section

AGE	FORMATION			
	NORTHWEST-2@	SOUTHWEST-4,5@	CENTRAL-9@	E.-CENTRAL-17@
Cenozoic				
Miocene	Various volc.		Various volc.	Various volc.
Pliocene	Various volc.		Various volc.	Various volc.
Oligocene		Various Tuffs	Various volc.	Various volc.
Eocene			Sheep Pass Fm.	White Sage Fm.
Paleocene				
Mesozoic				
Cretaceous	Ign. complex	Ign. complex	Ign. complex	
Jurassic	Volc. complex	Ign. complex Dunlap Fm. Sunrise Fm.	Ign. complex Aztec Ss. Kayenta equiv.	
Triassic	Boyer Ranch Fm. Lovelock-Muttlebury Fm. Various sands Auld Lang Syne Group Cane Spring Fm. Congress Cyn.-Augusta Mt. Fm. Prida Fm. Weaver Rhyolite	Gabbs Fm. Luning Fm.	Chinle Fm.	
Paleozoic				
Permian	Limerick Greenstone Edna Mt. Fm.	Mina-Diablo- -Black Dyke Fm.	Carlin Cyn. Fm. Beacon Flat Fm. Buckskin Mt.- -Carbon Ridge Fm. Strathearn Fm. Tomera Fm. Moleen Fm.	Park City Group Loray Fm. Pequop Fm. Ferguson Mt. Fm. Strathearn Fm. Ely Fm.
Permian-Penn. Pennsylvanian	Antler Peak Ls. Highway Ls.-Battle Fm.	unnamed chert		
Mississippian	Goughs Cyn. Fm.	Rest Spring Sh. Perdido Fm. Tin Mt. Ls.	Diamond Peak Fm. Chainman Joana Fm. Pilot Sh. Devils Gate Ls. Nevada Fm.	Chainman Fm. Joana Fm. Pilot Sh. Guimette Fm. Simonson Dolo. Sevy Dolo.
Devonian	Pilot Sh. Wenban Ls.	Squares Tun. beds Sunday Cyn. Fm.		
Dev.-Silurian Silurian	Roberts Mt. Ls.	Vaughn Gulch Ls.	Lone Mt. - -Rbts. Mt. Dolo.	Laketown Dolo.
Ordovician	Henson Ck. Fm. Eureka Qtzite.	Ely Springs Dolo. Johnson Spr. Fm. Barrel Spr.m. Mzourka-Pogonip Gp. Emigrant Fm.- -Bonanza King Dolo.	Henson Ck. Fm. Eureka Qtzite.	Ely Springs- Dolo.(upp.& lwr.) Eureka Qtzite. Crystal Peak Dolo. Watson Rch. Qtzite.
Cambrian	Comus Fm. Harmony Fm. Paradise Vy. Chert Preble Fm. Osgood Mt. Qtzite.- -Pioche Sh.- -Prospect Mt. Qtzite.	Mule Spring Ls. Harkless Fm. Poleta Fm. Campito Fm.	Pogonip Fm. Windfall Fm. Dunderberg Fm. Hamburg Dolo. Secret Cyn. Fm. Geddes Ls. Eldorado Dolo. Pioche Sh. Prospect Mt. Qtzite.	Pogonip Fm. Notch Peak Fm. Orr Fm. Wahwah Sum. Fm. Trippe Fm. Pierson Cove Fm. Eye-of-Needle Fm. Abercrombie Fm. Pioche Sh. Prospect Mt. Qtzite.

@ numbers refer to GREAT BASIN COSUNA chart general locations.

P-640, SACRAMENTO BASIN
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Pliocene	*Tehama Fm.
Miocene-Pliocene	Sycamore-Mehrten Fm.
Miocene	San Pablo Group
	Monterey Group
	Claremont Sh.
	Sobrante Ss.
	Valley Springs Fm.
Oligocene	Kirker Fm.
Eocene	*Markley Fm.
	*Nortonville Sh.
	*Domengine Fm.
	*Capay Fm.
	*Martinez Fm.
Paleocene	
Mesozoic	
Cretaceous	
Upper	Mokelumne River Sands-
	-Deer Valley Fm.
	H & T-Moreno Sh.
	Upper Delta Sh.
	*Starkey Sands
	Sawtooth-Upper Delta Sh.
	*Winters Ss.
	*Lathrop Sand-Lower Delta Sh.
	*Sacramento Sh.
	*Kione Ss.-Forbes Sh.
	Dobbins Sh. Mbr.
	*Guinda Ss.
	Funks Fm.
	*Sites Fm.
	Yolo Fm.
	*Venado Fm.
	Budden Canyon Fm.
Lower	Stony Creek Fm.
L. Cretaceous-Jurassic	Franciscan Series
Jurassic (?)	

* Currently producing # Potentially productive

Traps. Stratigraphic traps, including sandstone lenses and changes in carbonate facies, are probable traps in this area. Folds and faults are very likely traps. Combination traps may be most important.

Source rocks. Potential source rocks include the Tertiary Elko Formation and Sheep Pass Formation; the Upper Cretaceous Newark Canyon Formation; the Permian Meade Park Shale Member of the Phosphoria Formation; the Mississippian Deseret Limestone; and Chainman Shale; the Devonian Pilot Shale and Woodruff Formation; and the Ordovician Vinini Formation. Source rocks are moderately mature to severely altered in the province. Other shales and carbonate rocks may be potential source rocks in the area.

P-630, SOUTHEASTERN CALIFORNIA BASINS

This province includes the Mojave Desert, Salton Trough and Peninsular Ranges. Little is known about this nonproductive province. Marine Tertiary rocks are potential targets near San Diego adjacent to the San Andreas fault and along the Colorado River. The region has limited hydrocarbon potential.

P-640, SACRAMENTO BASIN

The Sacramento basin is the northern portion of California's Great Valley. It is bounded on the east by the Sierra Nevada Mountains, on the northeast by the Cascade Mountains, on the north by the Klamath Mountains and on the west by the Coastal Ranges. It is separated from the San Joaquin basin by the Stockton arch. The Sacramento basin is a structural and stratigraphic basin about 200 miles long and 70 miles wide. Over 30,000 feet of sediments were deposited in the deepest portion of the basin. These rocks are Upper Cretaceous and younger in age. Much of the basin is veneered with Holocene and Pleistocene alluvial deposits. This is an important natural gas province; most of it is non-associated gas.

Although more than 8,000 wells have been drilled in the Sacramento basin, only a relatively small number have made significant penetration beneath the base of the Upper Cretaceous F Zone or below 11,000 feet. These relatively unexplored deeper portions of the basin are considered less attractive because of the generally poor reservoir quality of the rocks and super pressures with hydrostatic gradients in excess of 0.7 psi/foot in many areas. The testing of these deeper formations and portions of the basin has not been adequate to condemn them as exploration objectives.

Reservoir rocks. The producing horizons in this province are Upper Cretaceous to Eocene in age. All are sandstones and include the Eocene Domenigine Sandstone and Capay Formation; the Paleocene Meganos and Martinez Formations and the Upper Cretaceous Starkey, Winters, Kione and Forbes Formations.

Traps. In this province, most gas accumulations are found in structural/stratigraphic trap combinations. Anticlines and faulted anticlines are very important. Most sandstones are either lenticular in nature or are submarine canyon deposits. Truncations and onlapping occur.

Source rocks. Numerous organic-rich shales were deposited with and between the sandstone units. Potential source rocks include the Starkey, Winters, Kione and Forbes Formations. Many Paleocene and Eocene shales may also be source rocks.

P-650, SAN JOAQUIN BASIN

The San Joaquin basin occupies the southern portion of California's Great Valley. It is an asymmetrical structural and stratigraphic basin with its axis in the western part of the valley and is approximately 250 miles long and 50 to 60 miles wide. It is bounded on the east by the Sierra Nevada Mountains, on the south by the Tehachapi Mountains, on the west by the Coast Ranges and on the north by the Stockton arch. More than 31,000 feet of Cretaceous and younger sedimentary rocks were deposited in this basin. Most of this is marine shales and sandstones, though continental deposits occur in younger intervals. The eastern portion of the basin is gently folded and faulted. The western portion is highly folded and thrust faulted. Sedimentary rocks were deposited from both eastern and western sources, resulting in different stratigraphy for the eastern and western portions of the province.

The San Joaquin basin is an important hydrocarbon province. The southern part of the basin mainly produces oil and associated/dissolved gas. Nearly all of this production is from Miocene and younger rocks. The northern part of the basin is an area of mostly non-associated natural gas production.

The flanks of the San Joaquin basin have been tested by thousands of wells. Most of these wells are shallow (less than 5,000 feet). Many wells in the basin have been drilled to depths between 10-15,000 feet along the basin margin and within the central basin. Depths greater than 15,000 feet have been tested only rarely. However, no significant encouragement at depths below 15,000 feet in the San Joaquin basin has been seen to date.

The Probable resources are likely to be found in field extensions and infill drilling. Possible resources are expected to be found in associated gas fields ranging in size from 0.25 to 100 Bcf. Most fields will average 1 to 12 Bcf of gas. Speculative resources are expected to be found in associated gas fields ranging in size from 10 to 150 Bcf with the average ranging from 10 to 20 Bcf.

Reservoir rocks. Nearly all reservoir rocks in the basin are sandstones. These range in age from Upper Cretaceous to Pleistocene. Included are the Upper Cretaceous to Tertiary Moreno Formation and numerous Tertiary and Pleistocene units. Some production is from Miocene fractured shales and from fractured basement schists.

Traps. All producing fields in the basin involve more than one trapping style. Anticlines and faulted anticlines are common and may be combined with one or more stratigraphic mechanisms. Common stratigraphic traps include sandstone pinchouts, truncations and diagenetically altered permeability.

Source rocks. Most of the shales in the basin are sapropelic. All are mature and are probable source rocks.

Trends. Producing trends in the province are the Bakersfield arch, West Side, East Side, Central Valley, South End Overthrust area, Paloma Deep production and the Northern Gas Province.

P-650, SAN JOAQUIN BASIN
Generalized Stratigraphic Section

AGE	FORMATION	
	NORTH & WEST	EAST
Cenozoic		
Pleistocene	*Tulare Fm.	
Pleistocene-Pliocene		Kern River Fm.
Pliocene	*San Joaquin Fm.	
Miocene-Pliocene	*Etchegoin Fm.	Etchegoin Fm.
Miocene		Macoma Claystone Mbr.
		Lerdo-Fairhaven sand
	Reef Ridge Fm.	Chanac Fm.
	*Santa Margarita-	U. Fruit. Sh.-Stevens Ss. Mbr.
	*McLure Fm.	"Pulv Zone " sand bed
		L. Fruitvale Shale
	Kettleman sand bed	
	*Big Blue-U. Temblor Fm.	Temblor Fm.-
		*Round Mt. Silt Mbr.
	*L. Temblor Formation	*Freeman Jewett Silt.
		Rio Bravo sand bed
		*Vedder Sand
Miocene-Oligocene		
	*Burbank Sand	
Oligocene	Whereley Sh.	
	*Vaqueros Ss.	
	Leda sand bed	
Eocene	Wagon Wheel- Tumey Fm.	Tumey Fm.
	*Kreyenhagen Sh.	*Kreyenhagen Fm.
	Domengine-*U. McAdams Ss.	
	Getchell-*L. McAdams Ss.	
	*Lodo Fm.	
	Arroyo Hondo Sh. Mbr.	
	Cantua Ss. Mbr.	
Paleocene	Cerros Sh. Mbr.	
	San Carlos sand bed	
	*Moreno Fm.-	
Mesozoic	-Dos Palos Sh. Mbr.	
Cretaceous	*Moreno Fm.	
Upper	*Panoche Group	
	Brown Mountain Ss. Mbr.	
	Ragged Valley Silt	
	Joaquin Ridge Ss. Mbr.	
	Alcalde Sh.	
	Los Gatos Ss. Mbr.	
	Waltham Canyon Fm.	
Lower	Long Canyon Ss.	
	Oak Flat Fm.-Curry Mt. Sh.	
	Dowdle Ss. Mbr.	
	Springs Road Ss.	
	Center Peak Cgl. Mbr.	
	Fresno Springs Canyon Sh.	
	Gravelly Flat Fm.	
	Wisenor Fm.	
Jurassic?	Franciscan Subduction Complex	
	* Currently producing	

P-660, CALIFORNIA COASTAL BASINS

This province is made up of the Coast Ranges, Transverse Ranges and six small basins. Large quantities of oil, associated/dissolved and non-associated gas are produced in this province. Most production occurs in the southern basins.

The Los Angeles basin is a triangular region about 70 miles long and 40 miles wide and extends offshore. It covers approximately 1,450 square miles and is bounded on the north by the San Gabriel Mountains, on the southeast by the Santa Ana Mountains and on the south by other parts of the Peninsular Ranges. More than 31,000 feet of Miocene and younger sedimentary rocks fill the deeper parts of the basin. Most of the basin is covered by Pleistocene alluvial deposits. Basin deformation began in the Miocene and culminated in the mid-Pleistocene. Major faults and folds trend northwesterly across the basin.

The Ventura basin is a long eastward-trending reentrant. It is bounded by two of the Transverse Ranges. Most of this basin is offshore. Compressional forces have formed east-trending anticlines and thrust faults in the basin. As much as 55,000 feet of sedimentary rocks were deposited within the onshore portion of this basin.

The Santa Maria basin is a wedge-shaped reentrant in the Coast Ranges. Sedimentary rocks are confined to 30 miles onshore but extend offshore. East-trending elongate folds cross the region.

The Santa Cruz basin is a wedge-shaped coastal basin. It covers approximately 260 square miles. It is bounded on the north and east by the San Andreas fault and Franciscan basement rock outcrops and on the south by Monterey Bay.

The Salinas-Cuyama basin is an elongate, northwest-trending onshore basin. It is about 160 miles long and 28 miles wide and covers 3,100 square miles. It is bounded on the southwest by the Nacimiento fault zone and on the northeast by the San Andreas fault zone. It contains more than 15,000 feet of Tertiary sedimentary rocks.

The Humboldt, or Eel River, basin is in northwestern California. It is triangular in shape and covers 575 square miles. It is bounded on the northeast and south by up-thrown basement rocks. It contains more than 12,000 feet of Miocene and younger rocks. Basin deformation occurred during the Pleistocene.

Reservoir rocks. The reservoir rocks in the Los Angeles basin are the Pliocene Pico and Repetto Formations; the Miocene Puente and Topango Formations and the fractured Jurassic Catalina Schist. Of these, the Repetto Formation is the most prolific. Reservoir rocks in the Ventura basin are the Pliocene Pico and Repetto Formations; the Miocene Rincon Claystone and Vaqueros Formation; the Eocene-Oligocene Sespe Formation and the Eocene Coldwater Sandstone. Of these, the Pliocene and Miocene are the most prolific. In the Santa Maria basin, the reservoir rocks are the Pliocene Foxen and Sisquoc Formations; the Miocene Monterey Formation; the Oligocene-Miocene Point Sal and Lope Formations and the Jurassic Knoxville Formation. Much of the production in this basin is from fractured reservoirs in cherts, shales and tight sandstones. In the Salinas-Cuyama basin, the main reservoirs are the Miocene Dibble Sandstone and the Miocene Lombardi Sandstone. In the Santa Cruz basin, production is from Eocene sandstones. Probable reservoirs in the Humboldt basin are the Pliocene Scotia Bluff Sandstone, Rio Dell Formation and Eel River Formation and the Miocene Pullen Formation.

Traps. The major trapping mechanisms in the Los Angeles basin and Humboldt basin are anticlines, faults and faulted anticlines. These are important trap formers in the other basins as well. Other trapping mechanisms include sandstone lenses, truncations and porosity variations in the Santa Maria basin. Sandstone pinchouts occur in all basins. Onlapping sandstones form traps in the Salinas-Cuyama basin. Fracture porosity is important in the Los Angeles, Santa Maria and Ventura basins.

Source rocks. The Miocene Monterey is a likely source rock in the Ventura, Santa Maria and Salinas-Cuyama basins. The Miocene Rincon Claystone is a probable source rock in the Ventura basin. In the Los Angeles basin, the source rocks are the Pliocene Repetto Formation and the Miocene Puente and Modelo Formations. In the Humboldt basin, the probable source rocks are the Pliocene Rio Dell and Eel River Formations and the Miocene Pullen Formation.

P-660, CALIFORNIA COASTAL BASINS
Generalized Stratigraphic Section

AGE	FORMATION		
	LOS ANGELES BASIN	VENTURA BASIN	SANTA MARIA BASIN
Cenozoic			
Pleistocene	San Pedro Fm.- La Habra Fm.	San Pedro Fm.- Saugus Fm. Santa Barbara Fm.	Orcutt Fm. Paso Robles Fm.- Santa Barbara Fm.
Plio-Pleist.	Fernando Fm.- San Diego Fm.		
Pliocene		*Pico Fm.- Sunshine Ranch Fm.	Careaga Ss.- Morales- *Foxen Muds
Mio-Pliocene	*Repetto Fm. Capistrano Fm.- Olay Fm.	Ridge Basin Group- Towsley Fm.	*Sisquoc Fm.
Miocene	*Puenta Fm.- Monterey Fm. "Santa Margarita" San Onofre Breccia *Topanga Fm.	Monterey- Castaic- Mint Canyon- *Modelo Fm. Topanga Fm. Tick Canyon Fm. *Vaqueros Fm.- Vasquez Fm.	Santa Margarita Fm.- *Monterey Fm. *Point Sal Fm. Lopse Fm- *Rincon Sh. Vaqueros Fm.
Olig.-Miocene	Vaqueros Fm.		Simmler- Alegria- Sespe Fm.
Oligocene			
Olig.-Eocene	Sespe Fm.	*Sespe Fm.	
Eocene	Santiago Fm.- Poway Group- La Jolla Group Matilija Fm.	*Coldwater Ss. Cozy Dell Sh.- *Llajas Fm. Matilija Fm. Santa Susana Fm.	Sacate Fm. Cozy Dell Sh.
Paleo.-Eocene			Pattiway Fm.- Anita Fm.
Paleocene	Silverado Fm.	"Martinez" Fm.- Coal Canyon Fm.	
Mesozoic			
Cretaceous			
Upper	Rosario Gp.- Williams- Ladd- Lusardi Fm. Trabuco Fm.	Chatsworth Fm.- Tuna Canyon Fm.	Jalama Fm.
Lower	missing	missing	Espada Fm. *Knoxville Fm. and Franciscan rocks
Jurassic			

* Currently producing

P-960 AND P-961, PACIFIC OFFSHORE, SHELF AND SLOPE

Many of the coastal deposits extend offshore and are especially important in the southern California regions. The Los Angeles, Ventura and Santa Maria basins all extend offshore and all present offshore production is confined to these extensions. Offshore southern California is composed of numerous horsts and grabens, and as much as 58,000 feet of sedimentary rocks lie in the offshore Ventura basin. The southern California region has good potential for future resource development. Although there is presently no production in offshore Washington or Oregon, the shelf is 30 to 40 miles wide and has potential for future development.

Reservoir rocks. Reservoir rocks in the California Offshore area include both sandstones and fractured shales. These range in age from Eocene to Pliocene. Included are the Eocene Sacate and Cozy Dell, the Oligocene Sespe, Alegria and Gaviota, the Miocene Vaqueros, Rincon, Monterey fractured shales and Puente and the Pliocene Repetto and Pico.

Traps. All producing fields involve faulted anticlines. Stratigraphic mechanisms such as truncations, sandstone pinchouts and diagenetically altered permeability also affect production.

Source rocks. Pliocene shales, the Miocene Monterey Formation and the Miocene Rincon Claystone are probable sources of most of the hydrocarbons.

Table 12. Estimated resources of natural gas for provinces of the Pacific Area, December 1988 (billion Cubic feet)

PROVINCE	ONSHORE depth	OFFSHORE water depth	PROBABLE			POSSIBLE			SPECULATIVE		
			Min.	M. likely	Max.	Min.	M. likely	Max.	Min.	M. likely	Max.
P-600, Oregon-Washington coastal basins, Okanogan	0-15,000'		*	*	*					1,700	5,000
P-610, Eastern Columbia Basin	15-30,000'									*	2,000
P-620, Great Basin-Southern Oregon	0-15,000'									1,000	3,000
P-630, Southeastern California basins	15-30,000'									*	2,000
P-640, Sacramento basin	0-15,000'									700	2,000
P-650, San Joaquin basin	15-30,000'									*	1,000
P-660, California coastal basins	0-15,000'									500	1,000
P-960, Pacific shelf	15-30,000'									*	*
P-961, Pacific slope										1,500	5,000
TOTAL, onshore	0-15,000'									*	*
TOTAL, onshore	15-30,000'									*	500
TOTAL, onshore, all depths										100	1,500
TOTAL, offshore										600	1,300
TOTAL, offshore										400	800
TOTAL, offshore, all depths										1,750	3,000
GRAND TOTAL FOR AREA										4,050	6,900

*Negligible quantity of natural gas estimated.

ALASKA AREA

With a total area of approximately 1.15 million square miles (about half of which is on land, the other half is between the shoreline and the -1,000-meter isobath), Alaska is a vast frontier. Oil production has been established on the North Slope and in the Cook Inlet area to the south (WSW of Anchorage). Natural gas production is currently restricted to the Cook Inlet area because of the lack of pipeline systems to bring North Slope gas to market.

Tectonically and stratigraphically, Alaska includes parts of the Rocky Mountain and Western North American Borderland settings. Producing, and prospectively productive, intervals are of Paleozoic age or younger. Geologic structures include both folds and faults. Reservoir lithologies range from sandstones to carbonate rocks.

The past two years (1987 and 1988) in Alaska have been marked by a drastic slowdown in exploration drilling because of low oil prices and a resulting reduction in exploration spending. Consequently, only four wildcats were spudded in 1987 and three in 1988. None of these was classified as a significant discovery, although the ARCO Point McIntyre #3 well helped to delineate about 250 Bcf of gas in a new pool just northwest of the Prudhoe Bay field. The almost total lack of activity gives no basis to alter previous estimates of potential gas resources in Alaska.

P-701, ALASKA NORTH SLOPE

The Alaska North Slope geologic province includes a total of 54,610 square miles and extends from the Beaufort Sea in the north to the Brooks Range in the south. The majority of Alaska's oil production currently comes from this area and is concentrated along the Barrow arch trend. The province also contains large reserves of natural gas (currently more than 31 Tcf proven), but there is no current gas production due to lack of pipeline facilities and a poor economic climate.

Reservoir rocks. Deposition along the Barrow arch took place in a linear, downfaulted basin located along a stable, passive cratonic margin. Potential reservoir rocks consist largely of Mississippian to Tertiary clastic rocks deposited in this basin. Current production comes from the Ellesmerian sequence of rocks, ranging in age from Mississippian to earliest Cretaceous, and from the Brookian sequence, ranging in age from Early Cretaceous to Tertiary. Principal sandstone reservoirs include the Permo-Triassic Sadlerochia Group (oil and gas), Triassic Sag River Formation (oil and gas), Early Cretaceous Kuparuk River Formation (oil and gas), sandstones of the Early Cretaceous Nanushuk Group (oil and gas), sandstones of the Late Cretaceous Colville Group (oil), Late Cretaceous West Sak sands (oil), and Tertiary Sagavanirktok Formation (gas). Carbonate reservoirs include the Mississippian-Pennsylvanian Lisburne Group (oil) and the Triassic Shublik Formation (oil and gas).

Traps. Accumulations in the Ellesmerian sequence are trapped by combinations of folding, faulting, and truncation by a major unconformity at the base of the Brookian sequence (Lower Cretaceous unconformity). Seals are generally provided by overlying shales or other less permeable rocks. Brookian sequence hydrocarbon accumulations appear to be due primarily to stratigraphic changes. Permafrost is believed to be a trapping mechanism for gas accumulations in the younger Brookian sequence.

Potential source rocks. Shales contained in Mississippian, Permian, Jurassic, Cretaceous and Tertiary sequences are the most likely source rocks for the hydrocarbon accumulations.

Future exploration. Based on the successful exploration efforts to date, the main exploratory interest in Alaska remains in the North Slope province and the adjacent Beaufort Sea province.

P-701, ALASKA NORTH SLOPE
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Quaternary	Gubik Fm.
Tertiary	Brookian sequence #Sagavanirktok Fm. #Flaxman Island sands #Ugnu Fm./#Point Thomson sands
Mesozoic	
Cretaceous	
Upper	Colville Group Prince Creek Fm. #West Sak sands Seabee Fm.
Lower	#Nanushuk Group/unnamed shale Okpikruak Fm. *Ellesmerian sequence *Kuparuk R. Fm./*Kemik Ss. *Kingak Sh.
Jurassic	*Karen Crk. Ss./*Sag River Fm.
Triassic	*Shublik Fm. *Sadlerochit Group (Ivishak Ss.)
Paleozoic	
Permian	
Pennsylvanian	*Lisburne Group
Mississippian	*Endicott Group (Kekiktuk Fm.)
Pre-Mississippian	Franklinian Sequence *Currently producing #Potentially Productive

**P-702, ALASKA SOUTHERN
FOOTHILLS AND BROOKS
RANGE**

This province encompasses the Brooks Range from the foothills in the north to the Koyukuk, Yukon Flats and Kandik basins which form the southern border. The area of the entire province totals 65,373 square miles. Tectonically the province has been classified as a deformed cratonic margin which has been associated with strong folding and overthrusting.

No oil or gas fields or producing trends have been established in this province to date. However, the

occurrence of bitumen, solid hydrocarbons and oil shale (Tasmanite) of Early Cretaceous age have been reported.

Reservoir rocks. Potential reservoir rocks range from Devonian reef carbonates of the Hunt Fork-Beaucoup Formation to the Cretaceous Torok Shale. Other potential reservoir rocks are included in the Endicott Group (Devonian-Mississippian), the Skajit Formation (Devonian-Silurian), Lisburne Group (Mississippian-Pennsylvanian), Shublik Formation (Triassic), and Fortress Mountain Formation (Early Cretaceous).

Traps. Prospective traps are considered to be related to thrust faults and faulted anticlines.

Potential source rocks. Shales and carbonate rocks, ranging in age from Devonian to Cretaceous are considered potential sources of hydrocarbons. These formations include Kayak Shale (Mississippian), "Kavik" Formation (Mississippian), Kingak Shale (Jurassic), and "pebble shale" (Early Cretaceous).

**P-703, YUKON FLATS BASIN
AND KANDIK BASIN**

This province includes a surface area of over 30,000 square miles and is divided into the Kandik basin and the Yukon Flats basin. Both basins are considered intermontane with sedimentary section possibly exceeding 20,000 feet. The one exploratory well in the Kandik basin encountered tectonically repeated overly mature Mesozoic rocks. The two exploratory wells in the Yukon Flats basin were drilled in the extreme northeast margin and encountered thermally mature Paleozoic rocks at total depth. Although only three wells have been drilled in this province, the prospect for gas production appears small.

P-704, ALASKA INTERIOR BASINS

This province stretches over nearly 260,000 square miles from the southern foothills of the Brooks Range in the north to the Alaska Range and the Chugach Mountains in the south. It is bordered on the west by the Bering Sea and on the east by the Canadian border. Several sedimentary basins are included in the province: Bethel basin, Inoko basin, Lower Tanana basin, Holitna basin, Yukon delta (onshore portion of Norton basin), Minchumina basin, Middle Tanana basin and Copper River basin. No production of oil or gas has been established in this province. However, the Bethel basin, Copper River basin, Minchumina basin, and Holitna basin are thought to have some potential for future natural gas production.

The southeastern basins generally contain Tertiary rocks overlying Precambrian basement. Generally, the shallow intermontane Minchumina and Middle Tanana basins contain non-marine molasse sediments which are thermally immature. Apart from coaly and carbonaceous material, the organic carbon content is low.

The northwestern portion of the province includes a thin Tertiary section which is probably thermally mature but contains a low organic carbon content. The Cretaceous section is thermally overmature. No shows have been reported in wells drilled to date.

The Copper River basin is a topographic basin floored with unconsolidated deposits of Quaternary age. In at least two localities in the south-central part of the basin, flammable methane gas associated with saline springs seeps through the Quaternary sediments. Mesozoic sediments crop out along the periphery of the basin. Exposures indicate a thick section of both Upper and Lower Cretaceous rocks underlain by a thinner sequence of Jurassic rocks which in turn are underlain by a series of Upper Triassic sedimentary rocks. Both the Jurassic and Cretaceous rocks are of marine origin and contain potential source rocks, in the form of organic shales, and potential reservoir sandstones. Triassic carbonates are also considered potential reservoirs. Wells drilled to date in the Copper River basin have encountered minor gas shows.

P-705, NORTHERN GULF OF ALASKA (ONSHORE)

This province encompasses approximately 15,000 square miles. It is bordered on the north by the Chugach Mountains, on the south by the Gulf of Alaska and on the east by the Canadian border. The major tectonic elements include the Yakataga and Yakutat basins. Nearly all rocks are of Tertiary age and consist almost entirely of detrital units. Prospective reservoir rocks range in age from Eocene to Miocene.

Oil production has occurred in the Katalla trend, on the shore of the Gulf of Alaska east of Cordova which is the only established production in southern Alaska outside the Cook Inlet area. Oil and gas seeps were discovered in the Katalla area about 1896 and the first successful well was drilled in 1902. A small refinery was built in 1911, but it burned down in 1933 and there has been no production at Katalla since then. About 36 wells were drilled, all comparatively shallow, from 550 to 750 feet in depth. Total oil produced from the field was about 154,000 barrels. Later onshore exploratory wells in the province have encountered minor oil and gas shows.

P-706, SOUTHEASTERN ALASKA

This province is bordered on the north, south and east by the Canadian border and by the Pacific Ocean on the west. It covers a total area of about 31,000 square miles. No oil or gas production has been established in the province to date. Most rocks in the province have undergone intense deformation so that it is difficult to assess their petroleum potential, if any. Predominantly they consist of metamorphic and crystalline rocks.

P-707, COOK INLET—SUSITNA PROVINCE (ONSHORE)

This province encompasses a total area of 45,568 square miles. The province is bounded on the north and west by the Alaska Range and by the Chugach and Cook Inlet in the south. The major tectonic elements include the Susitna basin, Matanuska Valley, Cook Inlet basin and Augustine-Sedovia arch. Producing trends established to date are the Sterling/Beluga trend and the Hemlock/Tyonek/West Foreland trend. A few oil and gas seeps, as well as subsurface shows, have been reported. Several gas fields and two oil fields are on production from this province.

Reservoir rocks. All prospective intervals consist of detrital rocks, mainly sandstones, and mainly of Tertiary age.

Traps. Both structural and stratigraphic traps occur at all reservoir levels. All production thus far is from anticlines and faulted anticlines. Caprocks include the Kenai Group siltstone (Oligocene-Pliocene) and the siltstone unit of the West Foreland Formation (Paleocene).

Potential source rocks. The Tertiary Kenai Group shales and claystones are considered potential source rocks for gas. The mid-Jurassic Naknek Formation is considered capable of generating both oil and gas.

P-708, ALASKA PENINSULA—SHELIKOF PROVINCE (ONSHORE)

This province encompasses a total area of 12,777 square miles. It is bordered on the north and west by the Aleutian Range and on the southeast by the Shelikof Strait. The major tectonic elements include the Wide Bay and Chignik anticlines and the Pearl Creek dome. The major stratigraphic units range in age from Triassic to Tertiary. Sandstone and conglomerate units form all reported potential reservoirs. No oil or gas production

P-707, COOK INLET—SUSITNA PROVINCE (ONSHORE); P-995, COOK INLET BASIN (OFFSHORE) Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic	
Tertiary	Kenai Group *Sterling Fm. *Beluga River Fm. *Tyonek Fm. *Hemlock Fm. *West Foreland Fm. Chickaloon Fm.
Mesozoic	
Cretaceous	Kaguyak Fm. Matanuska Fm. unnamed Herendeen Ls. Naknek Fm. Chinitna Fm. #Tuxedni Group Talkeetna Fm. Kamishak Fm.
Jurassic	
Triassic	

*Currently producing #Potentially productive

has been established in the province although several wells reported oil shows.

P-709, ALASKA PENINSULA—BRISTOL BAY (ONSHORE)

This province includes 22,187 square miles in southwestern Alaska. No production has been established, but potential for oil and both associated/dissolved and non-associated gas is envisaged. The region is bordered by the Aleutian Range on the southeast and by Bristol Bay on the northwest. Sedimentary rocks range in age from Jurassic to Pliocene and potential source and reservoir rocks exist throughout the section. Sandstones are the dominant lithology. A variety of structural and stratigraphic traps may exist. Wells drilled in the province have encountered minor oil and gas shows. A gas test well drilled in the Becharof area was abandoned as dry in 1985.

P-710, ALEUTIAN ISLANDS

This province includes the land area of the Aleutian Islands. It is located to the southwest of the Alaska Peninsula and encompasses a large number of mainly volcanic islands. The volcanic nature of the islands suggests negligible potential for natural gas.

P-971 AND P-972, BEAUFORT SEA SHELF AND SLOPE

These provinces cover a total area of approximately 40,000 square miles. The first commercial oil and gas field on the Beaufort Shelf is now being developed just north of the Sagavirktok delta and just northeast of the Prudhoe Bay field. Three other discoveries north and west from the Kuparuk delta are judged to be subcommercial with currently depressed oil prices, but optimism remains that major oil and gas reserves will be produced from the Beaufort Shelf region. No estimate has been made for potential which might exist below the continental slope at water depths from 200-1,000 meters because this area lies below the polar ice pack.

Reservoir rocks. Potential reservoir rocks are similar to the section in the adjacent onshore areas of the North Slope. The stratigraphic section contains rocks which range in age from Mississippian to Tertiary and are dominantly clastic rocks with the exception of Mississippian carbonates. Most of the prospective reservoir rocks occur in the Permo-Triassic section, but there are also some prospects in the Tertiary section to the east.

Traps. Stratigraphic traps are believed to be abundant. They include pinchouts (in Tertiary and Cretaceous units), truncations (Jurassic and Triassic rocks), and onlap in the Mississippian sequence. Structural traps are also postulated related to both folding and faulting.

Potential source rocks. Potential source rocks for both oil and gas exist in the Mississippian to Early Cretaceous sequence and in Late Cretaceous-Tertiary

rocks. The rocks range from thermally immature to very mature.

Future exploration. Most of the exploration plays to date consist of extensions of onshore trends. The difficulties of interpretation are exemplified by recent dry holes. The enormous potential of the adjacent onshore area and the likelihood of extensions of similar conditions into the offshore area are stimulants to continued exploration in spite of high costs and difficult conditions.

P-973, CHUKCHI SHELF

This province covers an area of approximately 61,000 square miles. No oil or gas production has been established to date. Potential reservoir rocks range in age from Mississippian to Tertiary. The rocks are predominantly clastic, although prospective reservoirs in Mississippian-age rocks are limestones and dolomites. Both stratigraphic and structural traps are anticipated. There has been no exploratory drilling to date in this province.

P-974, NORTON BASIN

This province covers an area of over 43,000 square miles. No oil or gas production has been established to date despite the drilling of six exploratory wells during 1984 and 1985. Prospective reservoir rocks range in age from Cretaceous to Tertiary and consist mainly of sandstones. Stratigraphic and structural traps are anticipated and have been noted in Tertiary rocks. Gas seeps, rich in carbon dioxide, have been reported from the area.

P-975, HOPE BASIN

This province is dominantly an offshore area, including mainly Kotzebue Sound and parts of the Bering Strait, but it also extends onshore to include a small area of the Seward Peninsula. Sedimentary rocks in the area range in age from Cretaceous to Tertiary. No natural gas or oil production has been established in the province.

The onshore portion is considered to have low potential for natural gas production. It contains a thin section of thermally immature, non-marine Tertiary sandstones, conglomerates and shales. The offshore portion has a thicker sedimentary section and is considered to have some potential from rocks of Cretaceous and Tertiary age. Both structural and stratigraphic traps may exist. Potential source rocks are primarily of Tertiary age.

P-979, ST. MATTHEW BASIN-BETHEL BASIN SHELF

This province includes an area of more than 91,000 square miles. No oil or natural gas production has been established, and the province is not considered to have potential for future natural gas production primarily due to a thin section of thermally immature rocks.

P-980, SOUTHWEST BERING SEA SLOPE

Water depths in this province are all greater than 1,000 meters. No estimate of natural gas potential has been made at this time.

P-981 AND P-982, NAVARIN BASIN, SHELF AND SLOPE

These provinces include an area of approximately 49,000 square miles covered by water depths of less than 1,000 meters. Sedimentary rocks range in age from Jurassic to Tertiary, and detrital units predominate. No production of natural gas or oil has been established in these provinces to date despite the drilling of nine exploratory wells during 1985. Potential reservoir rocks are of Jurassic, Cretaceous and Tertiary age. Both stratigraphic and structural traps are believed to occur. Pinchouts generally occur in Tertiary strata, whereas truncations and onlap are associated with Mesozoic rocks. Anticlines and faulted anticlines are common in Mesozoic as well as Tertiary units. Growth faults and draping also occur in the Tertiary section. Potential source rocks probably exist in the Jurassic, Cretaceous and early Tertiary sections.

P-983 AND P-984, ST. GEORGE BASIN, SHELF AND SLOPE

These provinces encompass an area of approximately 96,000 square miles. No oil or gas production has been established to date despite the drilling of nine exploratory wells during 1984 and 1985. Sedimentary rocks in the provinces are predominantly detrital and range in age from Jurassic to Tertiary. Potential reservoir rocks in the shelf province consist of sandstones of Jurassic, Cretaceous and Tertiary age. In the slope province, potential reservoirs for oil and gas are Paleogene (lower Tertiary) turbidites.

P-985, BRISTOL BAY BASIN SHELF

Approximately 55,000 square miles are included in this province which is all covered by water depths of less than 200 meters. Sedimentary rocks are generally detrital and range in age from Jurassic to Tertiary. No natural gas or oil production has been established to date. Potential reservoir rocks are sandstones of Jurassic, Cretaceous and Tertiary age. Both stratigraphic and structural traps occur. Truncations are most common in Mesozoic strata, whereas onlap and pinchouts appear restricted to Tertiary units. Faulted anticlines and faults are common at all stratigraphic levels. Potential source rocks are mostly of Cretaceous and early Tertiary age, although Jurassic units may also be a possible source.

P-987 AND P-988, SHUMAGIN-KODIAK SHELF AND SLOPE

This area lies offshore from southern and southwestern Alaska and encompasses an area of over 80,000 square miles. Sedimentary rocks are Cretaceous and younger, but Tertiary detrital units predominate. No natural gas or oil production has been established in the province. Potential for natural gas production is believed to occur in rocks of Tertiary age, generally sandstones, in the Shelf area. Traps may be either structural or stratigraphic. Most potential source rocks are in the Tertiary section.

P-989 AND P-990, ALEUTIAN SHELF AND SLOPE

The Aleutian Shelf and Slope cover an area of almost 85,000 square miles. Most of the rocks are related to the volcanic activity of the Aleutian Islands and to tectonic activity which formed the Aleutian Trench and the Islands. Most of the sedimentary rocks

are of younger Tertiary age. No production of natural gas or oil has been established in the province and the potential for future natural gas production is very low.

P-991, P-992, P-993 AND P-994, NORTHERN GULF OF ALASKA AND SOUTHEASTERN ALASKA SHELF AND SLOPE

These provinces have a combined area of approximately 56,000 square miles. Sedimentary rocks are predominantly of Tertiary age and are generally detrital. No production of natural gas or oil has been established. Potential reservoir rocks include Tertiary formations. Both structural and stratigraphic traps occur and include truncations and onlap as well as anticlines and faulted anticlines. Potential source rocks may occur within the early Tertiary section.

P-995, COOK INLET BASIN-OFFSHORE

This province is the offshore portion of the Cook Inlet basin; the onshore portion is included in province P-707. It covers slightly more than 7,400 square miles. Sedimentary rocks in the province are predominantly detrital and range in age from Jurassic to Tertiary. This, and the adjoining onshore province, is the only area of current natural gas and oil production in Alaska outside of the North Slope. Two trends of natural gas production and two trends of oil production have been established.

Reservoir rocks. Sandstones and conglomerates of Tertiary age are the primary gas and oil reservoirs. The Tertiary Beluga and Sterling Sandstones are productive of gas only.

Traps. Sandstone pinchouts and anticlinal trapping are both common in the Tertiary section. Truncation by unconformities and faulted anticlines are common trapping mechanisms in Mesozoic reservoirs.

Potential source rocks. Thermally immature to mature Tertiary rocks are considered a fair source for oil. Late Jurassic, thermally moderately mature to very mature, rocks are considered good sources for oil and possibly for gas.

P-991, P-992, P-993, and P-994, NORTHERN GULF OF ALASKA AREA,
SOUTHEASTERN ALASKA SHELF AND SLOPE
Generalized Stratigraphic Section

AGE	FORMATION
Cenozoic Tertiary	Tugidak Formation
	#Yakataga Formation
	Sitkinak Formation-#Katalla Formation
	#Poul Creek Formation
	#Tokun Formation
Mesozoic	Sitkalidak Formation-Orca Group- #Kulthieth Formation
	Ghost Rocks Formation
	Kodiak Formation-Valdez Group- Yakutat Group
	#Potentially productive

Table 13. Estimated resources of natural gas for provinces of the Alaska Area, December 1988 (billion cubic feet)

PROVINCE	ONSHORE		OFFSHORE		PROBABLE		POSSIBLE		SPECULATIVE	
	depth	water depth	Min.	Max.	M. likely	Min.	Max.	M. likely	Min.	Max.
P-701, North Slope province	0-15,000'		2,000	12,000	5,700	4,000	43,000	15,000	6,000	72,000
	15-30,000'								NO RELIABLE DATA	
P-702, Brooks Range province	0-15,000'								*	1,000
	15-30,000'								NO DATA	500
P-703, Yukon Flats-Kandik basins	0-15,000'								*	200
	15-30,000'								NO DATA	500
P-704, Alaska Interior basins	0-15,000'								*	2,500
	15-30,000'								NO DATA	500
P-705, Northern Gulf of Alaska, onshore	0-15,000'								100	3,550
	15-30,000'								NO RELIABLE DATA	
P-706, Southeastern Alaska	0-15,000'								*	*
	15-30,000'								*	*
P-707, Cook Inlet/Susitna province, onshore	0-15,000'		400	1,600	650	700	2,800	1,400	*	4,800
	15-30,000'								*	*
P-708, Alaska Peninsula/Shelikof province, onshore	0-15,000'								200	300
	15-30,000'								NO RELIABLE DATA	
P-709, Alaska Peninsula/Bristol Bay province, onshore	0-15,000'								400	1,400
	15-30,000'								NO RELIABLE DATA	
P-710, Aleutian Islands	0-15,000'								*	1,000
	15-30,000'								NO RELIABLE DATA	

* Negligible quantity of natural gas estimated.

Note: In addition to the Probable resource estimate of 5,700 Bcf for province P-701, North Slope province, reserves of approximately 32,000 Bcf have been demonstrated to exist in fields currently developed on the Alaskan North Slope according to estimates of the Committee on Natural Gas Reserves of the American Gas Association. Reserves of approximately 25,000 Bcf are included in reserve estimates published by the Energy Information Administration, US Department of Energy. These reserves are not carried in estimates of proved reserves prepared by some companies and might be considered as additional Probable resources.

Table 13 (continued). Estimated resources of natural gas for provinces of the Alaska Area, December 1988 (billion cubic feet)

PROVINCE	ONSHORE depth	OFFSHORE water depth	PROBABLE		POSSIBLE		SPECULATIVE	
			Min.	M. likely	Max.	Min.	M. likely	Max.
P-971, Beaufort shelf		0-200 m	1,000	2,000	11,000	3,000	12,000	41,000
P-972, Beaufort slope		200-1,000m						
P-973, Chukchi shelf		0-200 m						
P-974, Norton basin		0-200 m						
P-975, Hope basin		0-200 m						
P-979, St. Matthew shelf		0-200 m						
P-980, Southwestern Bering Sea		>1,000 m						
P-981, Navarin basin shelf		0-200 m						
P-982, Navarin basin slope		200-1,000m						
P-983, St. George shelf		0-200 m						
P-984, St. George slope		200-1,000m						
P-985, Bristol Bay shelf		0-200 m						
P-987, Shumagin shelf		0-200 m						
P-988, Shumagin slope		200-1,000m						
P-989, Aleutian shelf		0-200 m						
P-990, Aleutian slope		200-1,000m						
P-991, N. Gulf Alaska shelf		0-200 m						
P-992, N. Gulf Alaska slope		200-1,000m						
P-993, SE Alaska shelf		0-200 m						
P-994, SE Alaska slope		200-1,000m						
P-995, Cook Inlet, offshore		0-200 m	200	400	800	350	700	1,400
TOTAL, onshore	0-15,000'			6,350			16,400	
TOTAL, onshore	15-30,000'			*			*	
TOTAL, onshore, all depths				6,350			16,400	
TOTAL, offshore		0-200 m		2,400			12,700	
TOTAL, offshore		200-1,000 m		*			*	
TOTAL, offshore, all depths				2,400			12,700	
GRAND TOTAL FOR AREA				8,750			29,100	

*Negligible quantity of natural gas estimated.

NATURAL GAS RESOURCES FROM COAL SEAMS

INTRODUCTION

Coalbed methane, long considered an "unconventional" resource, is rapidly becoming a conventional resource. It is gaining importance as a viable new source of pipeline-quality gas, vying with production from such other "unconventional" gas-bearing reservoirs such as low-permeability ("tight") sandstones and fractured Devonian shales. Production of methane from coal seams is rapidly increasing; more than 30 Bcf is expected to be produced during 1989 from just two basins—the eastern Black Warrior, Alabama, and the northern San Juan, Colorado and New Mexico. It is estimated that between 1,000 and 2,000 coalbed methane wells will be drilled in these two basins during 1989-1990. One strong impetus for this greatly accelerated drilling activity is the "Nonconventional Fuel Tax Credit" (IRS Code Section 29); the qualifying period during which coalbed methane wells must be "drilled" (the precise definition of which has not been spelled out by the IRS) expires January 1, 1991. However, the "qualified fuel" produced from such wells is eligible to receive the tax credit—currently, about 80¢/million Btu's—until January 1, 2001.

Because of the growing importance of this new energy supply, with recoverable resources of coalbed methane expected to be more than 100 Tcf in the U.S., the Potential Gas Committee in 1986 established a new work committee to evaluate this resource. The Coalbed Methane Work Committee has as its assigned task the assessment of the magnitude of the coalbed methane resource that is recoverable from the coal deposits of the United States, utilizing technology that is available today or in the foreseeable future and assuming adequate economic incentives (excluding the present fuel tax credit). Many prominent coal-bearing basins in the

U.S. have yet to be evaluated for their coalbed methane potential. Reliable production histories spanning at least five to ten years exist in only a few coalbed methane fields or pools in the Black Warrior and San Juan basins. Therefore, coalbed methane is being treated in a separate chapter in this report. However, in the several cases where more detailed studies of such necessary parameters as available gas-content and well production data have supported computer simulation of coalbed methane reservoir behavior, the estimated recoverable coalbed methane resources have been included in the text for such geographic provinces. However, these gas resources have not been added to the PGC province or area totals. The PGC does not anticipate including coalbed methane resource estimates in its overall resource estimates until such time as more reliable quantitative data are available. These data include sustained production histories, reservoir behavior, areas of well interference, decline rates, and recovery efficiencies.

DEFINITION OF COALBED METHANE

Methane typically is the major hydrocarbon gas constituent evolved from coal during the coalification process, whereby peat material is slowly transformed by chemical reactions, or metamorphosis. Coalification is the chemical change that results in the generation of volatiles and the concomitant increase in the relative carbon content of fossil plant material. During the early stages of coalification, say, from peat to lignite, the humic kerogen present undergoes a biochemical stage of diagenesis when water, carbon dioxide, and biogenic

methane ("marsh gas") are produced. Coalification normally proceeds, if sufficient heat and pressure are present, evolving biogenic gas and, eventually, thermally generated (thermogenic) methane, plus water and CO₂. The change from biogenic to thermogenic methane generally takes place when the coal reaches high-volatile A bituminous in rank (vitrinite reflectance, R_o, of approximately 0.73%). Thermogenic methane continues to be generated as the rank increases to anthracite (R_o = 2.4%). The dry nonassociated gas, which is predominantly methane (occasionally, with a small percentage of heavier hydrocarbons) that today remains in the high-rank coals generally being exploited constitutes the bulk of the "coalbed methane" resource. In a broad sense, the biogenic gas in low-rank subbituminous coals, for example, also is classed as coalbed methane.

However, coal-derived methane now trapped in non-coal reservoirs, including low-permeability sandstones, is considered by the Potential Gas Committee to be a conventional gas resource and is being booked as such. Gas can be traced to a coalbed origin by virtue of its carbon-13 isotope values and deuterium concentrations. In order to "qualify" a well to receive the nonconventional fuels tax credit, the coalbed in question should be isolated during testing to demonstrate that the produced gas is in fact "coalbed methane."

RESOURCES OF COALBED METHANE

In-place resources. Figure 9 shows the estimated in-place resources of coalbed methane in the conterminous United States, as of December 31, 1988, for thirteen of the major coal-bearing basins in the U.S. The resource estimates listed on this map total 360 Tcf. Of the thirteen basins originally evaluated by the US Department of Energy/TRW Methane Recovery from Coalbeds Project (MRCP) during the period from 1979-1982 (Rightmire, et al., 1984¹), only five (indicated by the asterisks on the map) have been appraised in some detail by GRI/ICF Resources Incorporated.²

¹Rightmire, C. T., Eddy, G. E., and Kirr, J. N. (eds.), 1984, Coalbed methane resources of the United States: AAPG Studies in Geology Series #17, 378 p.

Table 14 summarizes the estimated coalbed methane resources of the thirteen major coal-bearing basins in the conterminous U.S. as determined by several published studies and by members of the PGC Coalbed Methane Work Committee. This table represents only an early stage of this committee's evaluation efforts. When compared with Table 18, Page 129, of the previous PGC biennial report (Potential Gas Committee, 1987³), Table 14 shows an increase in estimated total in-place methane for the assessed basins (133 to 448 Tcf vs. 72 to 429.4 Tcf in the previous report).

The Gas Research Institute's Natural Gas Supply Program currently is allocating approximately \$6.5 million to the Methane from Coal Deposits supply option. The tactical objective of this supply option is "... to provide the understanding, models, techniques, and tools necessary for the cost-effective recovery of methane from unminable coal deposits" (GRI, 1988, p. 59⁴).

²Kelafant, J. R., Wicks, D. E., and Kuuskraa, V. A., 1988, A geologic assessment of natural gas from coal seams in the Northern Appalachian Basin: ICF-Lewin Energy, Fairfax, VA, March, 84 p. (prepared for Gas Research Institute).

Kelso, B. S., Wicks, D. E., and Kuuskraa, V. A., 1988, A geologic assessment of natural gas from coal seams in the Fruitland Formation, San Juan Basin: ICF-Lewin Energy, Fairfax, VA, March, 54 p. (prepared for Gas Research Institute).

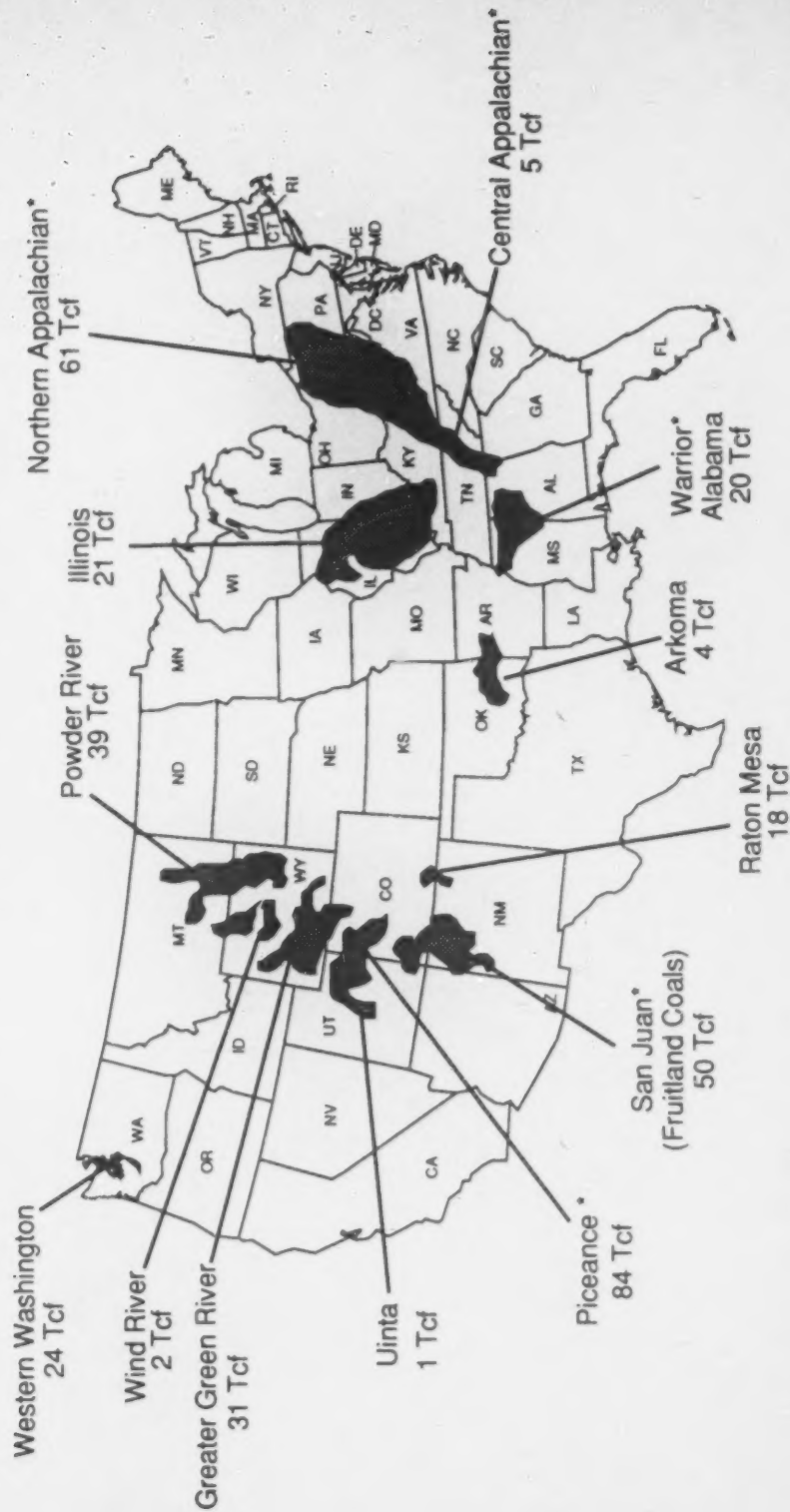
McFall, K. S., Wicks, D. E., and Kuuskraa, V. A., 1986, A geologic assessment of natural gas from coal seams in the Warrior Basin, Alabama: Lewin and associates, Inc., Washington, D.C., November, 84 p. (prepared for Gas Research Institute).

McFall, K. S., Wicks, D. E., Kuuskraa, V. A. and Sedwick, K. B., 1986, A geologic assessment of natural gas from coal seams in the Piceance Basin, Colorado: Lewin and Associates, Washington, D.C., November, 75 p. (prepared for Gas Research Institute).

³Potential Gas Committee, 1987, Potential gas resources from nonconventional sources—gaseous coal seams, in Potential Supply of Natural Gas in the United States (December 31, 1986): Potential Gas Agency, Colorado School of Mines, Golden, CO, May, p. 121-131.

⁴Gas Research Institute, 1988, 1989-1993 Research and development plan and 1989 research and development program: Chicago, IL, Gas Research Institute, June, 410 p (see especially p. 59-63, "Methane from Coal Deposits").

COALBED METHANE RESOURCES OF THE U.S.



*Detailed Geologic Appraisals Completed by GRI/ICF-Lewin

Table 14. Estimated coalbed methane resources, selected basins in conterminous United States.

PGC Region	Basin	PGC Province No.	State(s) included in evaluation	Estimated total methane in place (Tcf)	Estimated most likely recoverable resource, all resource categories (Tcf)
Eastern	Appalachian central*	P-120	KY, MD, TN, WV, VA	10.0 to 48.0 (1)	25 (2)
				5 (2)	
	Appalachian northern*	P-120	KY, MD, OH, PA, WV	61.0 (1)	
	Warrior (Black Warrior)*	P-150	AL, MS	5.0 to 10.0 (1)	
Western				19.8 (2)	8.0 (2)
				39.0 (3)	
	Illinois	P-220	IL, IN, KY	5.2 to 21.1 (1)	0.4 (4)
	Arkoma	P-410	AR, OK	1.6 to 3.6 (1)	
	Powder River	P-510	MT, WY	5.9 to 39.4 (1)	(not estimated)
	Wind River	P-520	WY	0.5 to 2.2 (1)	
	Greater Green River	P-530	CO, WY	0.2 to 30.9 (1)	(not estimated)
	Piceance*	P-540	CO	30.0 to 110.0 (1)	
				83.9 (2)	29.7 (2)
	Uinta/Wasatch Plateau	P-540	CO, UT	0.2 to 0.8 (1)	
	Raton Mesa (Raton)	P-545	CO, NM	8.0 to 18.4 (1)	(not estimated)
	San Juan*	P-555	CO, NM	1.8 to 31.0 (1)	
				50 (Fruitland coals only) (2)	27 (2)
	Western Washington	P-600	WA	3.6 to 24.0 (1)	
					(not estimated)
TOTAL ESTIMATED METHANE IN PLACE FOR ASSESSED BASINS				133 to 448	
TOTAL ESTIMATED RECOVERABLE METHANE (most likely estimate) FOR ASSESSED BASINS ONLY					90.1 to 97.1

*Coalbed methane production known to be established

(1) DOE MRCP (TRW)
(2) GRI/ICF-Lewin Energy
(3) University of Alabama
(4) Potential Gas Committee

Recoverable resources. Lack of complete understanding of the mechanisms of production of coalbed methane and limited production data make it difficult to estimate recoverable resources of coalbed methane. Some preliminary estimates for a few basins are included with this report together with the estimates of in-place resources (Table 14). The estimates of recoverable resources should be considered as tentative pending further investigations. Although much additional work needs to be accomplished by the Coalbed Methane Work Committee before an acceptable set of definitions for the PGC categories of Probable, Possible and Speculative can be finally adopted, the same general principles have been applied to estimation of coalbed methane resources as to other types of natural gas resources. The following general guidelines have been used.

For those basins where GRI/ICF Resources Incorporated have completed their geologic assessments, (1) their estimates of gas-in-place has been used as a starting point; (2) recoverable resources will be estimated by applying a recovery factor to (1), based on parameters such as production history, pressure decline/drawdown, and drainage area; and (3) estimates will be made for maximum, most likely, and minimum resources of coalbed methane for the probable, possible, and speculative categories.

For those basins where GRI/ICF Resources Incorporated estimates of in-place coalbed methane resources have not been made, the previous estimates, such as those published by US DOE/TRW, have been used, modified when possible by the most recent available data on coal volumes, gas contents, coal rank, etc. Where new data are not available, the most reasonable estimates of gas-in-place previously made have been used and recovery factors based on analogues with the nearest producing area have been applied.

All estimates of recoverable coalbed methane are based on that part of the resource that is judged recoverable with present or foreseeable technology; the cost or price of such gas will not be a direct consideration.

PRODUCTION OF COALBED METHANE

For hundreds of years, methane has been the scourge of underground coal mines. Furthermore, methane has been reported in shallow water wells and mining and petroleum test holes drilled through coal-bearing sequences for more than 100 years. Degasification boreholes, both vertical and horizontal, have been employed for safety reasons for a number of years in some gassy underground coal mines, dominantly in Appalachia (Skow and others, 1980⁵). The Big Run gas field, located in Wetzel County, northwestern West Virginia, has produced methane continuously since 1932 from an interval that includes the Pittsburgh coal bed. Since that time, the field has produced an estimated 2.3 Bcf of gas; one well made more than 200 MMcf of gas in about 36 years.

The Quarterly Review of Methane from Coal Seams Technology⁶ published by the Gas Research Institute, summarizes the drilling and production activities involving coalbed methane wells in the U.S.

The following is a summary of coalbed methane activity in the two most active basins in the U.S.—the Black Warrior and San Juan basins—based on information obtained from the Quarterly Review, ICF Resources Incorporated, and petroleum industry trade publications. Activity in other areas, such as the Piceance and Raton basins, Colorado, can be reviewed in recent issues of the Quarterly Review.

⁵Skow, M. L., Kim, A. G., and Deul, M., 1980, Creating a safer environment in U.S. coal mines—the Bureau of Mines Methane Control Program, 1964-79; U.S. Bureau of Mines Impact Report, Washington, D.C., 50 p.

⁶Gas Research Institute, 1983-, Quarterly Review of Methane from Coal Seams Technology; Published by GRI, Chicago, Illinois and printed by the Colorado School of Mines, Golden, CO (C. F. Brandenburg, Managing Editor; S. D. Schwochow, Production Manager).

1. BLACK WARRIOR BASIN, ALABAMA

The Black Warrior (or Warrior) basin is a triangular-shaped structural feature located in northwestern Alabama and northeastern Mississippi, encompassing some 35,000 square miles and bounded by sediments of Late Paleozoic age. It is a southern extension of the larger Appalachian basin, of Pennsylvanian age. The eastern-Black Warrior basin, Alabama, is relatively simple structurally, with gentle southwest dip, few folds, but common faults, mostly of normal displacement. The Lower Pennsylvanian Pottsville Formation is the only coal-bearing unit in the basin, containing upwards of 40 net feet of high-rank coal in the area of present drilling activity, at depths from the surface to more than 3,500 feet. The four major, or target, coal groups in the basin are, in descending order, the Cobb, Pratt, Mary Lee, and Black Creek. The east-central part of the basin contains the highest rank coal, low- to medium-volatile bituminous, with in-situ gas contents ranging from approximately 350 to 600-plus cubic feet/ton below a depth of ± 800 feet.

The eastern Black Warrior basin contains all the established coalbed methane, or coal degasification, fields in the state. This is one of the two most active areas of coalbed methane development in the world, the other being the San Juan basin. More than 500 coalbed methane wells have been drilled in the Black Warrior Basin since 1980 (Figure 10), with cumulative production in excess of 60 Bcf gas, which amounts to more than 25 percent of all the gas—chiefly from Mississippian-age sandstones—produced to date in the basin. More than 1,000 coalbed methane wells are expected to be producing in the basin by the end of 1989. The five active coal degasification fields in the Black Warrior basin currently are producing more than 58-MMcf gas/day; more than 90 percent of the production is derived from Brookwood and Oak Grove fields. Annual coalbed methane production in the basin has risen rapidly from approximately 5 MMcf in 1980 to an estimated 22 Bcf in 1988 (Figure 11).

To date, most of the produced gas has been derived from coal beds in the Mary Lee Group, at depths varying from 1,000 to 3,200 feet. Although most of the wells drilled to date have opened only one or two coal beds to production, the trend now is toward multiple-zone completions, where each target coal bed is selectively stimulated through staged hydraulic fracture

treatments (mainly sand-water). Average production currently is approximately 150 Mcf/day/well.

ICF Resources Incorporated estimates that the four main target coal groups in the basin contain 19.8 Tcf gas in-place; nearly 40 percent of this is in the Black Creek Group, the deepest of the four (McFall and others, 1986⁷). Although considerable work needs to be accomplished before accurate recovery factors can be corroborated, data obtained from control wells in the Oak Grove field indicate that more than 75 percent of the measured original gas in-place can be recovered from the coalbed methane wells in the immediate area (Briscoe and others, 1988, p. 245-246⁸).

Based on coalbed reservoir simulation techniques developed by ICF Resources Incorporated, the eastern Black Warrior basin is estimated to contain at least 8 Tcf of recoverable coalbed methane resources. This most likely estimate is divided as follows:

Probable Resources - 1.8 Tcf

Possible Resources - 1.2 Tcf

Speculative Resources - 5.0 Tcf
8.0 Tcf

Probable resources represent that quantity of gas located proximate ("step-out") to existing coalbed methane production and recoverable using existing technology. Possible resources represent that quantity of gas located in the remaining portion of the eastern Black Warrior basin and recoverable employing existing technology. Speculative resources represent that quantity of gas located in the larger part of the basin in which the necessary subsurface data are lacking and the recovery of which probably will require advanced technology.

⁷op. cit.

⁸Briscoe, F. H., Camp, B. S., Lottman, L. K., and Malone, P. G., 1988, A study of coal bed methane production trends as related to geologic features, Warrior Basin, Alabama, in *Geology and Coal-Bed Methane Resources of the Northern San Juan Basin, Colorado and New Mexico*, J. E. Fassett, ed.: Rocky Mountain Assoc. Geologists, Denver, p. 237-246.

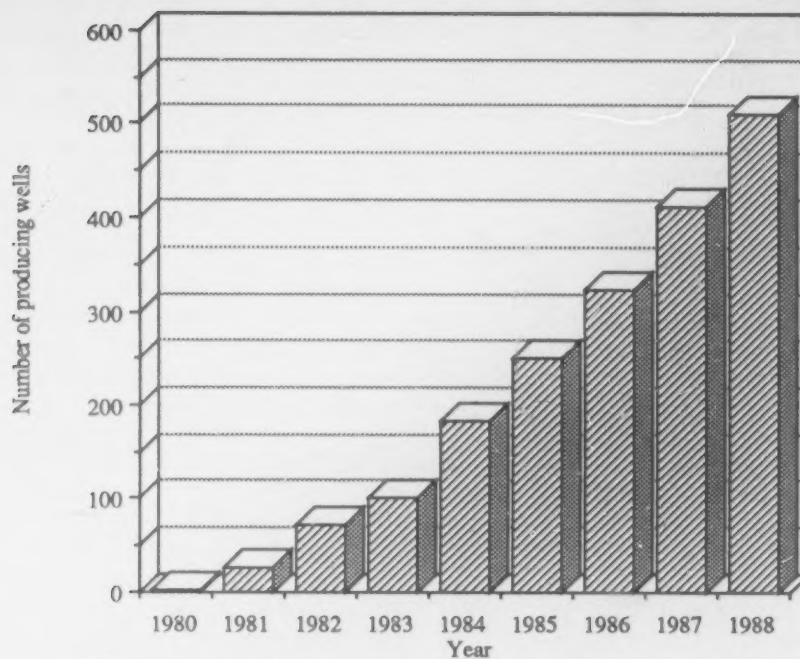


Figure 10. Producing coalbed methane wells in the Black Warrior basin, Alabama.
(data courtesy of State Oil & Gas Board of Alabama)

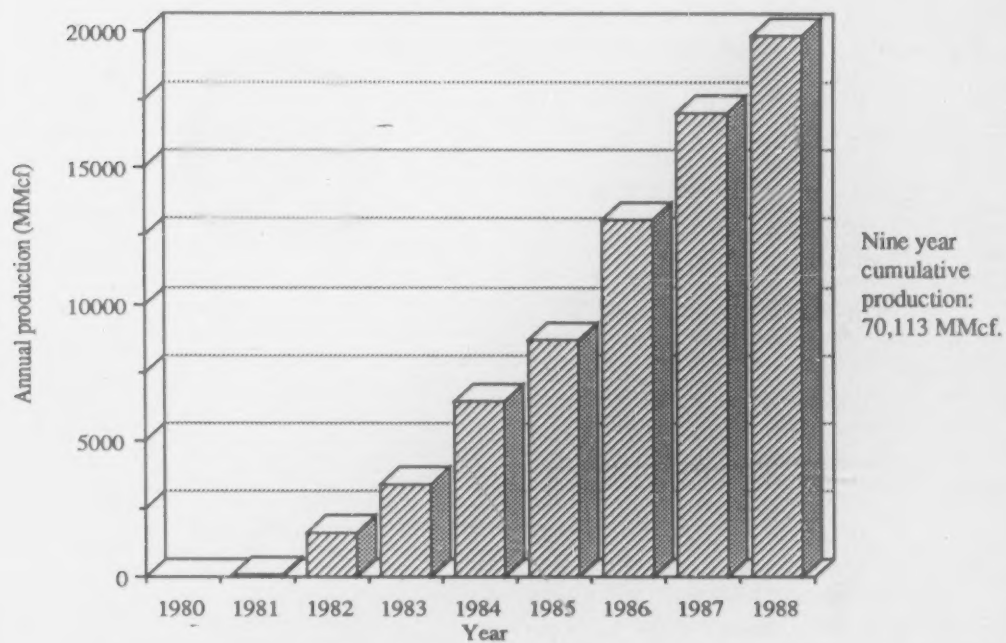


Figure 11. Annual production of coalbed methane in the Black Warrior basin, Alabama.
(data courtesy of State Oil & Gas Board of Alabama)

2. SAN JUAN BASIN, COLORADO AND NEW MEXICO

The San Juan basin, located in southwestern Colorado and northwestern New Mexico, is approximately circular in outline and encompasses some 15,000 square miles. This Laramide-age structural basin is asymmetric in shape and is bounded on the north, east and northwest flanks by steeply dipping monoclines.

The coal beds in the basin are contained within an Upper Cretaceous near-shore marine and deltaic-transitional sequence that is as much as 8,000 feet in thickness. Coal beds occur in this sequence in the Dakota Sandstone, Mesaverde Group, and Fruitland Formation, in ascending order. The multiple seams of coal in the Fruitland Formation, each of which can attain thicknesses in excess of 40 feet, constitute the most attractive coalbed methane resource target in the San Juan Basin. The Fruitland up to now has been the chief interval targeted for coalbed methane development in the basin. However, some operators currently are showing increasing interest in exploiting gas in coals in the deeper Menefee Formation (of the Mesaverde Group). The northern part of the basin contains the largest coalbed methane resource potential and is characterized by the greatest thickness of net Fruitland coal (as much as 80 feet), the highest heat flow and resulting high coal rank (up to low-volatile bituminous), and maximum in-place gas contents (200 to 450-plus cubic feet/ton of coal).

The development of coalbed methane in the San Juan basin is progressing at a rapid pace, with several hundred new wells slated for completion within the next year or two. Most of these are expected to be drilled by Amoco Production Co. and Meridian Oil Co. To date, more than 450 wells have been completed in Fruitland coals in the basin. Of these, production was reported in 1988 from 159 wells in the Ignacio Blanco, Cedar Hill and Meridian fields (Figure 12). Cumulative production over the past ten years from the same three fields is over 34 Bcf (Figure 13).

Typically, initial production rates vary from about 50 to 500 or more Mcf/day, usually with some water. However, Meridian Oil has completed several wells in Rio Arriba County, New Mexico, flowing at rates between 6 and 11 MMcf/day; these appear to be the most prolific coalbed methane wells in the world. Total depths of coalbed methane wells in the basin range

from approximately 1,200 to 4,100 feet, with the majority believed to have been completed at depths between about 2,000 and 3,500 feet.

Figure 14 shows the rapidly increasing production obtained from Cedar Hill field, New Mexico, which is operated by Amoco. The 16 wells here are on 320-acre spacing.

ICF Resources Incorporated estimates that the in-place methane resource in the Fruitland coal beds in the San Juan basin totals approximately 50 Tcf; most of this resource occurs in the northern part of the basin (Kelso and others, 1988⁹). Studies currently are under way by GRI/ICF Resources Incorporated to assess the coalbed methane potential of the Menefee coals in the basin.

Based on coalbed reservoir simulation techniques which model the unique storage and flow characteristics of methane in coal, ICF Resources Incorporated estimates that the Fruitland coals in the San Juan basin contain at least 27 Tcf of recoverable coalbed methane resources (the basin to date has produced more than 15.57 Tcf gas from Cretaceous-age sandstone reservoirs). This most likely estimate is divided as follows:

Probable Resources	-	4.0 Tcf
Possible Resources	-	3.0 Tcf
Speculative Resources	-	<u>20.0 Tcf</u> 27.0 Tcf

The definition of the above resource categories is the same as for the Black Warrior basin.

⁹op. cit.

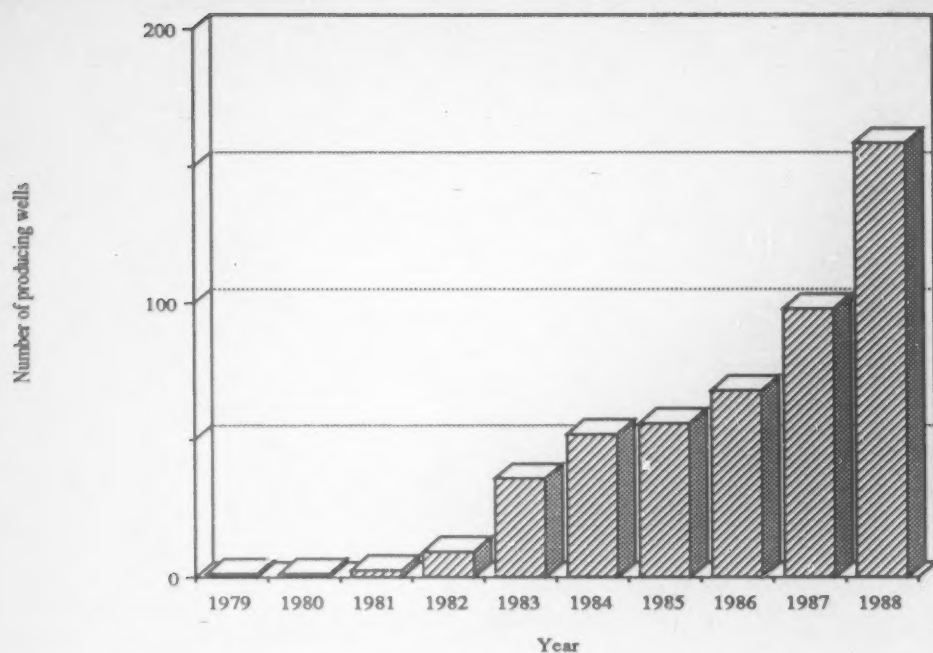


Figure 12. Coalbed methane wells, San Juan basin, Colorado and New Mexico. (data courtesy of ICF Resources Incorporated)

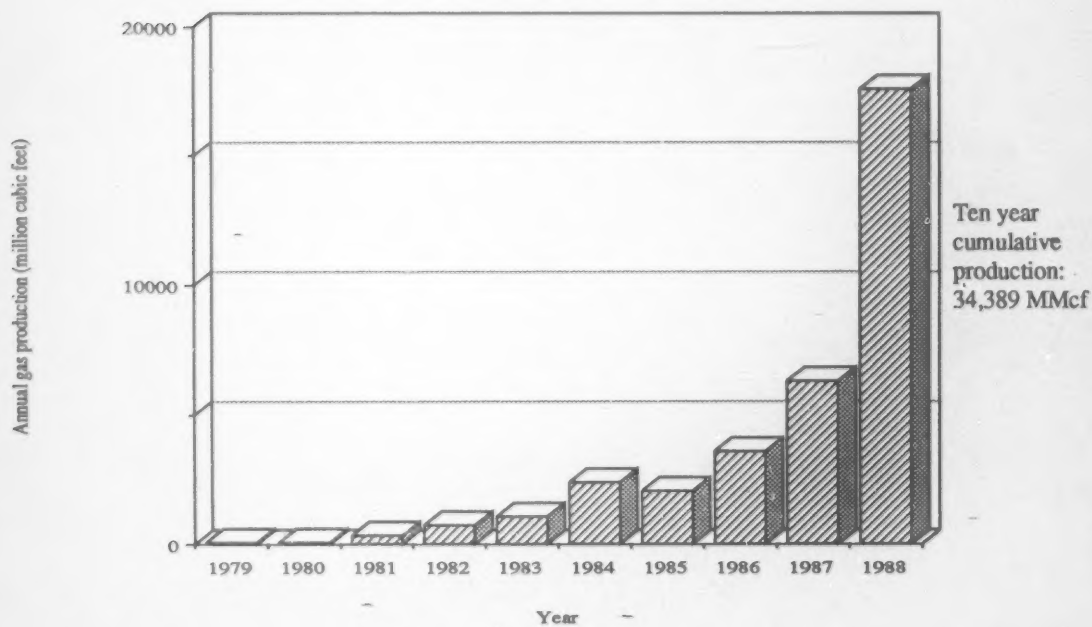


Figure 13. Annual production of coalbed methane (Ignacio Blanco, Cedar Hill and Meridian fields), San Juan basin, Colorado and New Mexico. (data courtesy of ICF Resources Incorporated)

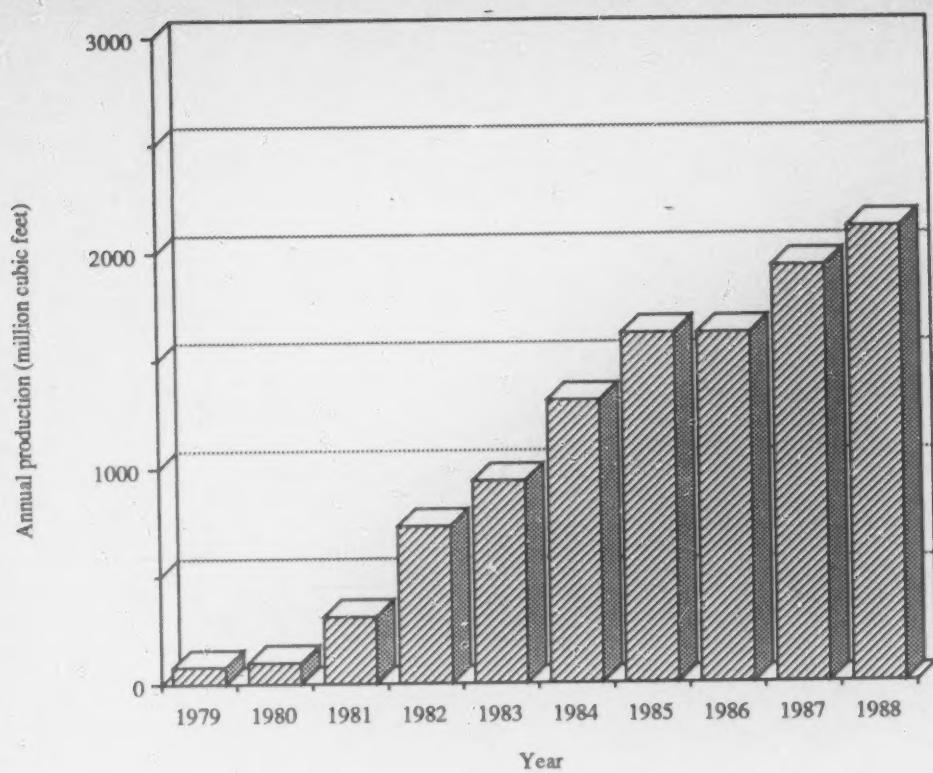


Figure 14. Annual production from Cedar Hill field, San Juan basin.
(data courtesy of ICF Resources Incorporated)

POLICY GUIDELINES

General Policy Statement

An appraisal of the long-range prospects of the natural gas industry in the United States—an appraisal that is useful for financial, managerial and government purposes—requires, as an essential element, scientific, authoritative, and objective estimation of the potential supply of natural gas which may become available to the nation in addition to currently available proved recoverable reserves of natural gas.

The Potential Gas Committee fulfills this requirement by providing periodic estimates of the potential supply of natural gas which may become available. The PGC, together with its several Area Work Committees, is composed of about one hundred fifty individuals from the production, transmission and distribution segments of the natural gas industry who are knowledgeable with respect to the potential supply of natural gas.

The Committee functions independently but with the guidance and assistance of the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association.

The PGC and its Area Work Committees discuss matters and data that are confidential. Fulfillment of the objectives of the PGC cannot be realized without the availability and utilization of information of a highly confidential nature. It is, therefore, the policy of the PGC and its Work Committees that every member, observer and representative will respect such information and that there will be no disclosure of information or estimates, discussions, or other data, except as approved for release by the PGC.

A diagram of the organizational structure for the estimation of the potential supply of natural gas is shown in Figures 14 and 15. A detailed description of

the membership and duties of the several committees and of the PGC is presented in the sections which follow.

Gas Supply Committee of the American Gas Association

The membership of the Gas Supply Committee consists of representatives of member companies of the American Gas Association selected by the Chairman of the Board and approved by the Board of Directors of the American Gas Association.

The scope of the Committee is to coordinate, motivate and make recommendations to the Board of American Gas Association as to the areas in which A.G.A. should become more active in the development of adequate gas supply for both short-term and long-term. In addition, the Committee undertakes special projects, where necessary, to evaluate industry gas supply programs. The Gas Supply Committee oversees the work of the Potential Gas Agency.

The primary duties and responsibilities of the Gas Supply Committee with relation to potential gas studies include the following:

- a. Establishing policy and objectives.
- b. Providing required financial support.

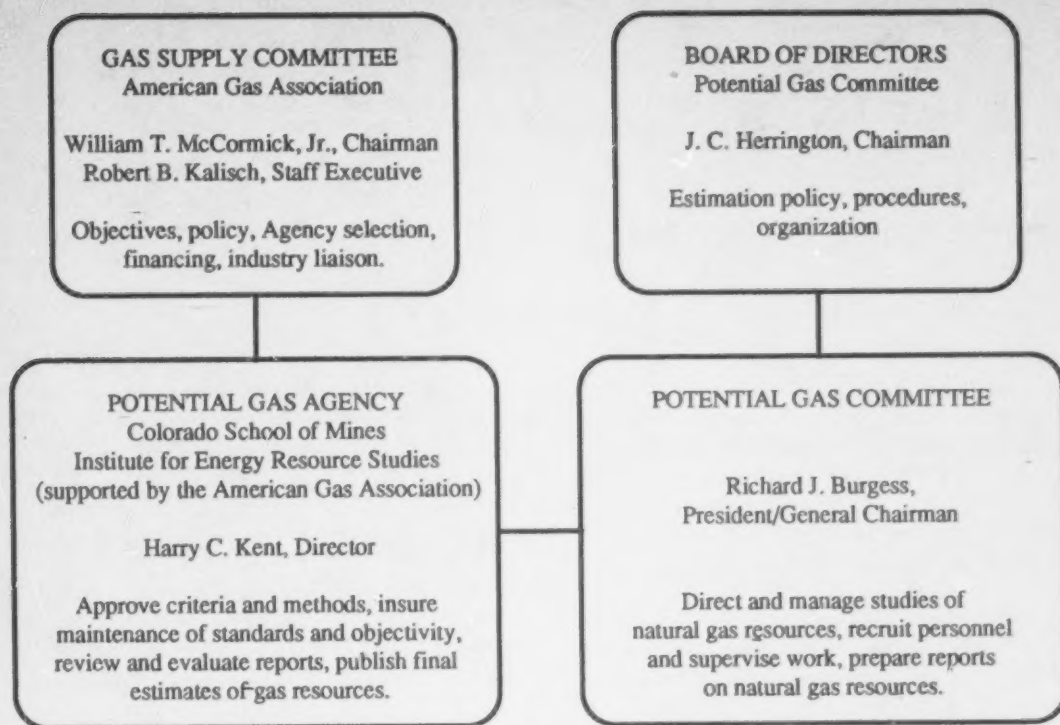


Figure 15. Organization of Potential Gas Resource Studies.

c. Maintaining liaison with industry and industry organizations.

d. Selecting the Potential Gas Agency.

e. Approving the appointment of the President/General Chairman and Regional Vice Presidents of the Potential Gas Committee by the Potential Gas Agency.

f. Appointing pipeline and distributor representatives to the Potential Gas Committee as may be necessary or advisable.

g. Appointing such other members and observers to the Potential Gas Committee as may be necessary or advisable.

h. Assisting in procurement of qualified manpower to staff properly the Potential Gas Committee and the Area Work Committees.

The Gas Supply Committee of the American Gas Association takes no part in the work or the deliberations of the Potential Gas Committee or its sub-committees. The Gas Supply Committee does not participate in the studies leading to the estimates of potential

supply of natural gas, and it neither approves nor disapproves the definitions and procedures, the estimates, or the report.

Potential Gas Agency of the Colorado School of Mines

The Potential Gas Agency functions under the direction of the Vice President for Academic Affairs of the Colorado School of Mines. The School, with the approval of the Gas Supply Committee, appoints staff personnel to the Potential Gas Agency.

The Potential Gas Agency is supported by the American Gas Association. The American Gas Asso-

POTENTIAL GAS COMMITTEE

Richard J. Burgess, President/General Chairman
 J. C. Herrington, Chairman, Board of Directors and Chairman, Time and Site Committee
 David A. Rochester, Secretary
 William E. Mantek, Chairman, Editorial Committee

Under direction of Potential Gas Agency, outline study; establish criteria and methods; designate and instruct Area Work Committees; supervise, coordinate and compile estimates made by Work Committees.

- Membership:
- a) President/General Chairman and Regional Vice Presidents--appointed by Potential Gas Agency and approved by A.G.A. Gas Supply Committee.
 - b) Area Work Committee Members.
 - c) Potential Gas Agency Director, Ex-officio.
 - d) Technical Advisors and Honorary Technical Advisors.
 - e) A.G.A. staff—one voting representative.
 - f) One Pipeline and one Distributor representative, designated by the Gas Supply Committee—voting representatives.
 - g) Observers from the federal government: Department of Energy, Energy Information Administration; Federal Energy Regulatory Commission; Department of Interior, Geological Survey, Bureau of Land Management, Minerals Management Service, Bureau of Mines; and such other government agencies as the Gas Supply Committee and the Potential Gas Agency shall approve—one nonvoting observer each, and alternates, if desired.
 - h) Gas Research Institute, Institute of Gas Technology, Natural Gas Supply Association, Electric Power Research Institute, Association of American State Geologists, Interstate Natural Gas Association of America, National Association of Regulatory Utilities Commissioners and Interstate Oil Compact Commission—one nonvoting observer each, and alternates, if desired.
 - i) Canadian and Mexican natural gas industry—one observer each, and alternates, if desired.
 - j) Others appointed by the Gas Supply Committee and approved by the Potential Gas Agency.

AREA WORK COMMITTEES

EASTERN REGION

Jeffery V. Morris, Regional Vice President

<u>Area</u>	<u>Chairman</u>
Atlantic	James M. Wigal
North Central	Michael W. Barratt
Gulf Coast	J. Scott Jenkins
Mid-Continent	Mike H. Knobloch

WESTERN REGION

Robert D. Habbit, Regional Vice President
 D. Keith Murray, Assistant Vice President

<u>Area</u>	<u>Chairman</u>
Rocky Mountain	H. O. Woodbury
Pacific	Peter D. Yu
Alaska	Donald C. Hartman
Coalbed Methane	D. Keith Murray

Figure 16. Organization of Potential Gas Committee

ciation is free, however, to take independent views of the operations and the studies produced by the Agency and its committees. The Agency is charged with the maintenance of scientific standards and objectivity of studies and publishes the reports of the Potential Gas Committee. The Agency appoints the President/General Chairman and Regional Vice Presidents of the Potential Gas Committee, approves the appointment of members, representatives and observers to the Potential Gas Committee and the chairmen of all sub-committees.

The Potential Gas Agency includes the following:

- a. A Director, appointed by and responsible to the Colorado School of Mines.
- b. Such additional staff personnel as may be required.
- c. Members of the faculty of the Colorado School of Mines or other qualified individuals who may, from time to time, provide such professional services as the Director of the Potential Gas Agency and the President/General Chairman of the Potential Gas Committee may determine necessary or desirable for discharging the duties of the Potential Gas Agency and the Potential Gas Committee.

The primary duties and responsibilities of the Potential Gas Agency include the following:

- a. Approving criteria and methods established by Potential Gas Committee, including protecting the confidentiality of Potential Gas Committee data.
- b. Insuring maintenance of the highest scientific standards and objectivity in Potential Gas Committee studies and reports.
- c. Reviewing and evaluating reports prepared by the Potential Gas Committee.
- d. Publishing, distributing and publicizing reports of final estimates and other pertinent reports prepared by the Potential Gas Committee so as to assure the widest possible distribution and to promote understanding of them.
- e. Further develop mutual understanding among the segments of the gas industry by helping the Gas Supply Committee unite the industry behind the potential gas studies.
- f. Help improve industry-government relations in the public interest looking toward maximum acceptance and usefulness of potential gas studies.
- g. Fulfill the professional obligation to publish technical papers concerning new techniques and knowledge gained.

h. Appointing President/General Chairman and Vice Presidents of Potential Gas Committee, with approval of Gas Supply Committee.

i. Approving appointment by Gas Supply Committee of other members, representatives and observers to the Potential Gas Committee.

j. Approving appointment of President/General Chairman of Potential Gas Committee, of Chairman of each Work Committee and chairmen of other committees.

k. Conduct the work of the Potential Gas Agency, in the public interest, in a manner which will enhance the stature of the Colorado School of Mines.

l. Adhere to the highest standards of objectivity.

The Colorado School of Mines may pursue other research, and individuals from the Agency may be involved in other research, consulting and preparation and publication of papers in their professional fields, so long as these activities do not involve a conflict of interest nor invalidate the objectivity of the Agency.

Potential Gas Committee

The Potential Gas Committee comprises members, representatives and observers from the producing, pipeline and distribution branches of the gas industry, together with observers from the American Gas Association, the Department of Energy, the Federal Energy Regulatory Commission, the US Geological Survey, the National Association of Regulatory Utility Commissioners, the Interstate Oil Compact Commission, the Bureau of Mines, the Gas Research Institute, Institute of Gas Technology, Association of American State Geologists, Electric Power Research Institute, Natural Gas Supply Association, Energy Information Administration, Interstate Natural Gas Association of America, Bureau of Land Management, Minerals Management Service and representatives from Canada.

The President/General Chairman of the Potential Gas Committee is assisted by the two Regional Vice Presidents and by a Board of Directors, composed of senior members of the Potential Gas Committee, including past chairmen. It is the function of the Board

of Directors to advise the President/General Chairman on policy matters.

An Editorial Committee is charged with approving the content of the report of the Potential Gas Committee.

The Definitions and Procedures Committee has the responsibility of reviewing and recommending to the membership of the Potential Gas Committee any proposed changes in the definitions and procedures used in the estimation of potential gas resources.

Membership of the Potential Gas Committee specifically includes the following:

- a. President/General Chairman of Potential Gas Committee.
- b. Secretary of Potential Gas Committee.
- c. Regional Vice Presidents and Assistant Vice Presidents.
- d. Chairman of each Area Work Committee.
- e. Chairman of Board of Directors.
- f. Chairman of Editorial Committee.
- g. Chairman of Committee on Definitions and Procedures.
- h. Chairman of Time and Site Committee.
- i. Director of the Potential Gas Agency, ex-officio.
- j. Observers from:
 - Association of American State Geologists
 - Bureau of Land Management
 - Bureau of Mines
 - Department of Energy, Energy Information Administration
 - Electric Power Research Institute
 - Federal Energy Regulatory Commission
 - Gas Research Institute
 - Institute of Gas Technology
 - Interstate Natural Gas Association of America
 - Interstate Oil Compact Commission
 - Minerals Management Service
 - National Association of Regulatory Utility Commissioners
 - US Geological Survey
- k. Representative from the natural gas pipeline industry.
- l. Representative from the natural gas distribution industry.
- m. Representative from the American Gas

Association

- n. Observer from the Canadian natural gas industry and observer from the Mexican natural gas industry.
- o. Technical Advisors and Honorary Technical Advisors.
- p. Representatives and observers from other organizations may be recommended for appointment by the Potential Gas Agency Director and approved by the Gas Supply Committee.

All members of the Potential Gas Committee, except those specifically designated as observers, are considered as voting members of the Potential Gas Committee. Observers are invited and encouraged to participate in discussion of items brought before the Potential Gas Committee but do not have a vote in the determination of policy and procedure. Alternates to representatives and observers may be appointed.

Candidates for Committee President/General Chairman and Vice Presidents normally will be geologists or persons with geology background from the academic community, pipelines, independent firms, gas utilities or producing companies. Retired or semi-retired gas industry people are not excluded from consideration.

Officers of the Potential Gas Committee and Area Work Committees are appointed as outlined in the Organizational Chart (Figure 9). Normally, they serve for a period of one report. They are eligible for reappointment, however, for one additional report period. In calculating eligibility for reappointment, a partial term of office shall not be counted. This policy shall not operate to disqualify a member from longer service by reason of elevation in the organization. In other words, the two-term limitation shall apply to each position held, considering each membership or officership on a work committee or top committee as a separate position.

All officers, regional vice presidents and the pipeline and distributor representatives appointed by the American Gas Association Gas Supply Committee shall be subject to the two-report limit. Exceptions must be recommended by the appropriate Committee Chairman and the Potential Gas Agency Director and approved by the American Gas Association Gas Supply Committee.

Technical Advisors include persons who have special knowledge of the occurrence of natural gas or the natural gas industry and whose expert advice will contribute to the successful performance of the Committee's assignments. Past Chairmen of Work Areas and Past Regional Vice Presidents of the Potential Gas Committee will be appointed as Technical Advisors if they are willing to continue to participate in the work of the Committee. The appointment of Technical Advisors is approved by the Gas Supply Committee upon recommendation by the Potential Gas Agency Director. Technical Advisors are appointed for the preparation of a specific PGC report. Their appointment may be continued indefinitely but is subject to review and approval at the time of organization of the Potential Gas Committee for each succeeding report.

The designation of Honorary Technical Advisor may be given to such persons as have performed exceptional service to the Potential Gas Committee and whose continued participation and advice are desirable for the continued successful operation of the Committee. Honorary Technical Advisors are permanent voting members; their appointment is recommended by the Board of Directors and approved by the Potential Gas Agency Director and the Gas Supply Committee.

Observers from sponsoring associations, governmental agencies and other cooperating groups serve at the discretion of these organizations and are not subject to the two-report policy.

The primary duties and responsibilities of the Potential Gas Committee include the following:

- a. Outlining the scope and coverage of the estimates of potential natural gas supply.
- b. Establishing criteria and methods for estimation of potential natural gas supply and other pertinent studies.
- c. Designating Work Areas and Special Projects.
- d. Appointing the Chairman of each Area Work Committee (by action of President/General Chairman of Potential Gas Committee).
- e. Approving appointment of other members of each Area Work Committee who are appointed by the Chairman of each Area Work Committee (by action of President/General Chairman of Potential Gas Committee).
- f. Instructing Area Work Committees.

- g. Supervising, coordinating, advising, reviewing, evaluating, approving and compiling estimates and such other assignments as may be given to committees.

- h. Preparing reports of final estimates and such other reports as may be pertinent.

- i. Submitting reports of final estimates and other pertinent reports to the Potential Gas Agency and counseling with Director regarding publication and distribution of such report.

Area Work Committees

Seven Area Work Committees are the backbone of the Potential Gas Committee. Each of the Work Committees has the responsibility of developing an estimate of the potential supply of natural gas in a particular part of the United States. Following the system long used by the petroleum industry, each Area Work Committee is assigned geologically significant areas (without specific regard to state lines) in which the Committee members have expert working knowledge. These Committee members with their fund of information (often confidential), are the source of knowledge and judgment for estimating the undiscovered gas supply in each area. Because geologic rather than geographic divisions are used, publication of estimates by individual states is not feasible.

The membership of Area Work Committees consists of employees and consultants associated with the producing, pipeline and distribution segments of the gas industry—as well as qualified personnel from State and Federal Agencies and educational institutions.

For administrative purposes, the Area Work Committees are grouped together in two regions: Eastern and Western. Each of these regions is supervised by a Regional Vice President who coordinates activities of the Area Work Committees within his jurisdiction and works with the Potential Gas Committee President/General Chairman in order to assure that there is an open flow of communication in both directions, and that the established techniques for resource estimation are being followed by the Area Work Committees.

Membership of Area Work Committees includes the following:

- a. Chairman of each Area Work Committee.
- b. An appropriate number of qualified working members deemed necessary by the Chairman of each Work Committee to insure the most objective estimates of potential supply of natural gas in the respective area assigned. Work Committee members are individuals from the natural gas and oil industries and other individuals who are qualified by their knowledge and experience to make estimates of potential supply of natural gas. The individuals are selected for each area because they have a close, working knowledge in all aspects of natural gas exploration and production.
- c. At least one qualified representative on each Area Work Committee from the natural gas pipeline industry, appointed by the Gas Supply Committee. (This requirement is currently waived for the Alaska Committee.)
- d. At least one qualified representative on each Area Work Committee from the natural gas distribution industry, appointed by the Gas Supply Committee. (This requirement is currently waived for the Alaska Committee.)

The Chairman and Vice Chairman of each Area Work Committee are subject to the two-report limit. Exceptions must be recommended by the Regional Vice President, approved by the Potential Gas Committee President/General Chairman and the Potential Gas Agency Director, and reported to the Gas Supply Committee, and only after receiving a clearance letter from the member's employer.

Other members of the Area Work Committees, appointed by the Area Chairman, will normally participate in the preparation of two successive reports. Service beyond the preparation of two reports may be continued if necessary to maintain adequate expertise and continuity on the Area Work Committee. Continuation of service beyond two reports must be recommended by the Area Chairman and approved by the Regional Vice President, the Potential Gas Committee President/General Chairman, and the Potential Gas Agency Director.

The primary duties and responsibilities of Area Work Committees include the following:

- a. Appointing appropriate number of qualified working members to insure proper representation of various sectors of the industry and objectivity for the best estimates of potential supply of natural gas for assigned areas (by action of Chairman of each Area Work Committee).
- b. Estimating quantity of potential supply of natural gas in working areas designated by the Potential Gas Committee pursuant to the guidelines and parameters established by the Potential Gas Committee, and approved by the Potential Gas Agency, and such other studies as may be assigned by the Potential Gas Committee.
- c. Performing such other assignments as may be made in the respective area assigned by the Potential Gas Committee regarding such estimate.

Each member of each Area Work Committee will submit his estimates of potential supply of natural gas and such other assignments as may be given to him in his assigned sub-area to the Chairman and other members of his committee for review, evaluation and approval.

Since the type and quantity of available information upon which to base estimates of potential natural gas supply vary widely from area to area, the Area Work Committee members use varied approaches in making their estimates. Inasmuch as the individual members work with private information obtained on a confidential basis from many sources, their working papers are not revealed in detail to anyone, including other members of the same Area Work Committee or others in the Potential Gas Committee. Without such confidential information, the Potential Gas Committee could not perform its task; therefore, each member, observer or representative of the Work Committees is aware of and must respect the confidential nature of the data made available to him and of the estimates and other assignments prepared or reviewed by the Area Work Committees and the Potential Gas Committee.

Standing Committees of the Potential Gas Committee

Board of Directors

The Board of Directors shall serve as the administrative coordinating committee for the Potential Gas Committee. It shall consider and discuss any matters of policy brought to its attention and shall make recommendations to the Potential Gas Committee regarding changes in policy. It shall act on behalf of the Potential Gas Committee on matters of urgency which arise between regularly scheduled meetings of the Potential Gas Committee. It may also be empowered to act on behalf of the Potential Gas Committee on matters designated by the Potential Gas Committee. At such times as vacancies occur in the following offices, the Board of Directors shall either act as a nominating committee to recommend suitable candidates or appoint a nominating committee from among its membership: PGC President/General Chairman, Regional Vice Presidents, Secretary of the PGC and Chairman of the Board of Directors.

Chairmen of PGC standing committees, with the exception of the Board of Directors, will be appointed by the PGC President/General Chairman, subject to approval by the Board of Directors. All actions of the Board of Directors will be reported to the membership of the Potential Gas Committee at their next regularly scheduled meeting and shall be subject to review and approval by the Potential Gas Committee.

Membership: Chairman, elected from the membership of the Potential Gas Committee by the voting members of the PGC at a regular meeting. Nominations for Chairman will be made by the Board of Directors and nominations will also be received from the floor. Normally, the Chairman will be elected at the fall meeting following publication of the biennial PGC report and will serve for two years. Vacancies will be filled by election at the next regular PGC meeting, following the same procedure and a Chairman so elected will serve for the remainder of the unexpired term. In the absence of the elected Chairman, the President/General Chairman of the Potential Gas Committee will serve as Chairman of the Board of Directors.

The following ex officio voting members: PGC President/General Chairman, PGC Regional Vice Presidents, Secretary of the PGC, Potential Gas Agency Director, Chairmen of Standing Committees, representatives appointed to the PGC from the natural-gas pipeline and natural-gas distribution industries, representative from the Canadian gas industry, representative from the American Gas Association.

In addition, a maximum of five voting Technical Advisors may be appointed by the Potential Gas Committee President/General Chairman, subject to approval by the Potential Gas Agency Director.

Editorial Committee

The Editorial Committee will review and approve the editorial content and format of PGC reports. They will work closely with the Potential Gas Agency in the publication of all official publications of the Potential Gas Committee.

Membership: Chairman, appointed by the Potential Gas Committee President/General Chairman, and approved by the Board of Directors. Six members of the Potential Gas Committee, appointed by the Editorial Committee Chairman, with approval of the PGC President/General Chairman. PGC President/General Chairman, ex officio; Potential Gas Agency Director, ex officio.

Committee on Definitions and Procedures

This Committee has the responsibility of reviewing and recommending to the membership of the Potential Gas Committee any proposed changes in the definitions and procedures used in the estimation of potential gas resources. Proposals to be reviewed by this Committee may be submitted by any member of the Potential Gas Committee. The Committee will further review estimates of potential gas resources made by other organizations which come to the attention of the Committee and may, from time to time, as deemed appropriate, prepare publications dealing with the comparison of the work of the Potential Gas Committee with that of other organizations. The Committee on

Definitions and Procedures will also serve as liaison with the US Geological Survey, Minerals Management Service and other such organizations as are involved in the work of estimation of potential gas resources.

Membership: Chairman, appointed by the PGC President/General Chairman and approved by the Board of Directors. Four members of the Potential Gas Committee, appointed by the Chairman of the Committee on Definitions and Procedures, with approval of the PGC President/General Chairman. PGC President/General Chairman, ex officio; PGA Director, ex officio.

Time and Site Committee

This Committee will select an appropriate location and date for each national PGC meeting which will serve best the needs of the Committee. Once the site and date of each meeting have been selected by the Committee, the Potential Gas Agency will be charged with the responsibility of completing the arrangements for the meeting. The Time and Site Committee will also coordinate any regional meetings which are scheduled by Regional Vice Presidents in order that the dates of such meetings shall not be in conflict.

Membership: Chairman, appointed by the PGC President/General Chairman and approved by the Board of Directors. Three members of the Potential Gas Committee, appointed by the Chairman of the Time and Site Committee and approved by the PGC President/General Chairman. Regional Vice Presidents, ex officio; PGC President/General Chairman, ex officio; PGA Director, ex officio.

Communications

Communication Between Committees

The formal channel of communication shall be from the Area Work Committees to the Potential Gas Committee to the Potential Gas Agency to the American Gas Association Gas Supply Committee and vice versa.

Public Communication

Members of the Potential Gas Agency, the Potential Gas Committee and the Area Work Committees are encouraged to publicize and explain their work. These efforts should be limited to explaining the methodology used, comparative methodology and the strengths and limitations of the work. When acting as spokesmen for the Committee, members shall refrain from interpreting study results in terms of national policy needs or required industry incentives. Members who are called upon to make talks and write papers on behalf of the Committee should submit texts to the Potential Gas Agency for comment and policy review.

MEMBERSHIP OF THE POTENTIAL GAS AGENCY AND POTENTIAL GAS COMMITTEE

POTENTIAL GAS AGENCY

Harry C. Kent, Executive Director
Joseph J. Finney, Associate Director
Sharon J. Kirts, Staff Assistant

POTENTIAL GAS COMMITTEE

Richard J. Burgess, President/General Chairman
Jeffery V. Morris, Vice President, Eastern Region
Robert D. Habbit, Vice President, Western Region
David A. Rochester, Secretary

Board of Directors

Donald W. Axford	J. C. Herrington, Chairman	Jack Lewis
Billy D. Brown	Robert E. Hodge	William E. Mantek
Richard J. Burgess	E. Floyd Humphries	Jeffrey V. Morris
A. M. Derrick, Jr.	Robert B. Kalisch	D. Keith Murray
Robert D. Habbit	Harry C. Kent	David A. Rochester
John D. Haun	Sharon J. Kirts	

Editorial Committee

William E. Mantek, Chairman	
A. M. Derrick, Jr.	David A. Rochester
J. Scott Jenkins	ex officio:
Mike H. Knobloch	Richard J. Burgess
Charles L. Neumeyer	Harry C. Kent

Committee on Definitions and Procedures

John D. Haun, Chairman	
A. M. Derrick, Jr.	ex officio:
Donald E. Hallinger	Richard J. Burgess
J. C. Herrington	Harry C. Kent

Time and Site Committee

J. C. Herrington, Chairman
ex officio:
Richard J. Burgess
Harry C. Kent

AREA WORK COMMITTEES

EASTERN REGION

Jeffery V. Morris, Vice President

Atlantic

James M. Wigal, Chairman

Richard L. Stollar, Vice Chairman

E. Perry Bendler
William E. Bennett
Porter J. Brown
Michael R. Canich, Jr.
Thomas E. Dimelow

Neil E. Foreman
George C. Grow, Jr.
William W. Kelly, Jr.
Wayne S. Leeper

Roy W. Lynch, Jr.
Marshall S. Miller
Carl W. Sherman
Arthur M. Van Tyne

North Central

Michael W. Barratt, Chairman

Richard J. Burgess
Gerard DeBusschere
H. Jerry Hodgden

Richard H. Howard
Merlin A. Johnson
Stanley J. Keller

Curtis L. Lundy
William E. Mantek
Ira R. Satterfield

Gulf Coast

J. Scott Jenkins, Chairman

Gordon Marney, Vice Chairman

H. Sherman Anderson
Floyd J. Ball
Charles R. Brammell
Donovan W. Darsey
Thomas J. Donlon
Neil E. Foreman
Maurice A. Gilbert

Stephen C. Hurley
James P. Kaiser
Gregory L. Kennamore
John C. Kucewicz, Jr.
John H. McElroy
Eugene Myers
Mike Nowicki

Robert L. Peters
Edgar A. Rassinier
David A. Rochester
Scott A. Roth
Daniel M. Semetko
Dan Titerle
Lee R. Tramel

Mid-Continent

Mike H. Knobloch, Chairman

Louis F. Marczyński, Vice Chairman

Louis A. Blanchard
Billy D. Brown
Louie P. Chrisman
Kenneth H. Dwight
Benjamin M. Heider, III

Michael Kemen
Robert M. Knebel
Larry F. London
Rick Pankau

Norris E. Pedigo
Kenneth R. Perkins
Garry D. Wilson
James C. Woodson

WESTERN REGION

Robert D. Habbit, Vice President
D. Keith Murray, Assistant Vice President

Rocky Mountain

H. O. Woodbury, Chairman
Marshall C. Crouch III, Vice Chairman

Edward M. Allshouse
Sidney Anderson
Walter Arbuckle
James A. Barlow, Jr.
Ronald A. Baugh
Duane Buckner
David Fischer

C. Keith Fisher
Lee C. Gerhard
William B. Hanson
John D. Haun
David H. Hawk
Douglas W. Hollett
Moid U. Kidwai

Frank E. Kottowski
Stephen T. Luthy
Richard B. Powers
Ron W. Pritchett
Richard W. Szepe
John J. Tonnsen
William L. Vaughan

Pacific

Peter D. Yu, Chairman
Kenneth R. Wainwright, Vice Chairman

William F. Edmondson
Dwayne L. Foley
Larry J. Garside

Kenneth F. Hersh
Jon H. Luksch

Douglas Waterman
Frank E. Weagant

Alaska

Donald C. Hartman, Chairman

David M. Hite
Richard Drumheller
Roger Stickney

Coalbed Methane

D. Keith Murray, Chairman

Kenneth L. Ancell
Charles F. Brandenburg
A. David Decker
J. Read Holland
James P. Kaiser

Bruce S. Kelso
Vello A. Kuuskraa
Fred F. Meissner
Marshall S. Miller
Ron W. Pritchett

Technical Advisors

James A. Barlow, Jr.
E. Perry Bendler
William E. Bennett
Charles R. Brammell
Billy D. Brown
Richard J. Burgess
Billy C. Cook

William F. Edmondson
Robert W. Gallagher
Donald E. Hallinger
John D. Haun
Wallace A. Howes
Merlin A. Johnson
John C. Kucewicz, Jr.

Lester E. Ludwick
Curtis L. Lundy
William E. Mantek
Henry B. Martch
Alexander Sisson
Edward J. Sondey

Honorary Technical Advisors

Charles M. Allen
Donald W. Axford
B. Warren Beebe
Porter J. Brown
Charles J. Crowley

James K. Curry
A. M. Derrick, Jr.
George C. Grow, Jr.
John M. Hanley

E. Floyd Humphries
Richard J. Murdy
Charles Neumeyer
Edgar A. Rassinier

Representatives

Donald W. Axford
Robert E. Hodge
Mike Lambert
Robert B. Kalisch

Representative, Canadian
Representative, Pipelines
Representative, Distributors
Representative, American Gas Association

Observers

Ellis R. Boyd, Jr.,
Philip M. Budzik,
John S. Bulger,
Lucio A. D'Andrea,
W. Timothy Dowd,
Daniel A. Dreyfus,
E. Bruce Hagen,
Danny Hill,
Tommie C. Hillis,
Robert V. Lang,
John E. Latz,
Bernard S. Lee,
Barry G. Luft,
Hans Maciej,
John B. Maher, Jr.,
Paul E. Martin,
Richard D. Miller,
Patrick O'Shea,
Jeremy Platt,
Dudley D. Rice,
Darrell L. Sala,
Wayne M. Thompson,
Merlin J. Tipton,

Division of Reserves & Natural Gas, DOE/EIA
Natural Gas Supply Association
Gaz Metropolitan, Inc. (Canada)
Economic Commission for Europe
Interstate Oil Compact Commission
Gas Research Institute
National Assn. of Regulatory Utility Commissioners
Interstate Natural Gas Association of America
Federal Energy Regulatory Commission
Gulf Canada Resources Ltd. (Canada)
Bureau of Land Management, DOI
Institute of Gas Technology
Western Gas Marketing Ltd. (Canada)
Canadian Petroleum Association (Canada)
Polaris Petroleum Ltd. (Canada)
Minerals Management Service, DOI
U.S. Bureau of Mines
Gas Research Institute
Electric Power Research
U. S. Geological Survey, DOI
Institute of Gas Technology
Federal Energy Regulatory Commission
American Association of State Geologists

ALLEN, Charles. M. (12)*: Oil and Gas Consultant, Crystal River, FL (1987-); Oil and Gas Consultant, Homosassa Springs, FL (1981-87); Phillips Petrol. Co., empl. var. capacities Expl. and Prod. Dept., Bartlesville, OK (1944-81); Adv. Board Dept. Geol., Univ. KS (1973-76). Mem. Am. Assn. Petrol. Geol. (Comm. Emerg. Prep. 1974-76, Comm. U.S. Energy Outlook 1970-73), Fed. Power Comm. Nat. Gas Surv. (Gas Supply Task Force 1971-75). Has testified in numerous state conservation agency, state, fed. courts, Fed. Power Comm. proceedings (incl. all major area, nat'l rate proceedings), hearings before Sen., House Congr. Comm., PGC Hon. Tech. Adv.

**ALLSHOUSE, Edward M. (6): Consulting Reservoir Geol., El Paso Nat. Gas Co., El Paso, TX (1973-). Mem. Am. Assn. Petrol. Geol. (former SW Sect. Del.) (CPG #3262), Am. Inst. Prof. Geol. (#7257), Am. Inst. Min., Met. & Petrol. Engr. (Past Chmn., El Paso Chapter), El Paso Geol. Soc. (Past Pres.), PGC Rocky Mtn. Area Comm.

ANCELL, Kenneth L. (2): V. Pres., Dowdle Fairchild & Ansell, Inc., Houston, TX (1982-); Enhanced Energy Res., V. Pres., Houston, TX (1981-82); INTERCOMP Res. Dev. & Engr., Gen. Mgr. Gas Proj., Houston, TX (1976-81); Chief Res., Engr., Panhandle Eastern Pipe Line Co., Liberal, KS, Houston, TX (1965-76). Mem. Soc. Petrol. Engr., Soc. Petrol. Eval. Engr., Lic. Prof. Engr., TX, KS, WY, NV, NJ, PGC Coalbed Methane Comm.

ANDERSON, H. Sherman (4): Chief Geol., CXY Energy, Inc.; Chief Geol., Moore McCormack Energy, Inc., Dallas, TX (1981-), Eastern Dist. Expl. Mgr. (1979-81); Jackson Expl., Dist. Geol., Dallas, TX (1979); Lear Petrol., Area Geol., Dallas, TX (1978-79); Universal Res., Dist. Geol. Dallas, TX (1978.); Ensearch Expl., Sr. Staff Geol., Dist. Geol., Geol., Tyler, TX., Jackson, MS., Dallas, TX (1964-78); Diamond Shamrock, Jr. Geol., Geol., Amarillo, TX (1955-64). Mem. Am. Assn. Petrol. Geol., PGC Gulf Coast Area Comm.

+ Number in parentheses indicates number of Potential Gas Committee reports in which member has participated.

ANDERSON, Sidney (2): State Geol., ND Geol. Surv., Grand Forks, ND. PGC Rocky Mtn. Area Comm.

ARBUCKLE, Walter K. (3): Ind. Geol., Fossil Assoc., Inc., Denver, CO (1957-); Kinbark Co., Geol., Denver, CO (1953-57); British American Oil Co., Engr. (1949-53). Mem. Am. Assn. Petrol. Geol., Am. Inst. Min. Engr., Rocky Mtn. Assn. Geol., PGC Rocky Mtn. Area Comm.

AXFORD, Donald W. (10): Pres., D. W. Axford & Assoc. Ltd, Calgary, Canada (1977-); Pres., Trax Petrol. Ltd., Calgary (1987-); Columbia Basin Energy Corp., Pres., U.S. (1982-); Petro-Canada, V. Pres. Expl. & Prod. (1976-77); Mobil Oil (Canada & U.S.), V. Pres. Expl. & Dir. (1948-76). Dir. Highridge Expl. Ltd., Mem. Am. Assn. Petrol. Geol., Assn. Prof. Engr., Geol. & Geophys. Alberta, Canadian Soc. Petrol. Geol., Geol. Soc. Am., Geol. Assn. Canada, Soc. Econ. Paleon. & Min., PGC Bd. Dir., Canadian Rep., Hon. Tech. Adv.

BALL, Floyd J. (4): Dir. Gas Reserves & Deliverability, Transcont. Gas Pipe Line Corp., Houston, TX (1986-); So. Nat. Gas Co., Dir. Gas Reserves (1981-85), Mgr. Reserves Engineering (1978-81), Sr. Engr. (1975-78), Engr., Birmingham, AL (1968-70). Mem. Nat. Gas Assn. of Houston, Soc. Petrol. Engr., Prof. Engr. TX, PGC Gulf Coast Area Comm.

BARLOW, James A. Jr. (7): Pres., Barlow & Haun, Inc., Casper, WY (1957-); Forest Oil Corp., Geol. (1953-57); Ohio Oil Co., Geol. (1952-53). Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Scient., Rocky Mtn. Assn. Geol., WY Geol. Assn., PGC Tech. Adv., Rocky Mtn. Area Comm.

BARRATT, Michael W. (5): V. Pres. Expl., Pendleton Land & Expl., Englewood, CO (1987-); PPG Oil & Gas Co., Gen. Mgr., Denver, CO (1985-87); Ladd Petrol. Corp., Mgr. MI Basin Div., Jackson, MI (1984-85); Patrick Petrol. Co., Mgr. MI Basin Div., Jackson, MI (1980-84); MI Oil Co., Mgr., MI Basin Div., Alma, MI (1978-80), Staff Geol. (1975-78); MI Gas Util. Develop. Co., Staff Geol., Hastings, MI (1972-75); MI Consolidated Gas Co., Staff Geol., Detroit, MI (1969-72). Mem. Am. Assn. Petrol. Geol., MI Basin Geol. Soc. (Past Pres., V. Pres., Treas.), MI Oil and Gas Assn. (Bd. Dir.), PGC Chmn. North Central Area Comm.

BAUGH, Ronald A. (1): Consulting Geol., Assoc in Geol., Casper, WY (1978-); Retained by Monsanto Oil Co., WY (1979-85); Runge & George, Consulting Geol., WY (1974-78). Mem. WY Geol. Assn. (1st V. Pres. 1989), Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol. (Sect. Pres. 1988, Natl. Adv. Bd. 1989), PGC Rocky Mtn. Area Comm.

BEEBE, B. Warren (12): Ret., Denver, CO (1980-); Geol., Geophys. & Energy Consultant, Boulder, CO (1972-80); Millison & Beebe, (Partner) (1969-72); M. M. & B., Inc., V. Pres. & Sec. (1964-72); Ind. Geol., Geophys. (1959-64); Keating Drilling Co., V. Pres., Dir. (1955-58); Manhart, Millison & Beebe, Partner (1950-55); Anderson-Prichard Oil Corp., Expl. Mgr. (1947-50); Bay Petrol. Corp., Chief Geol., Expl. Mgr. (organized Expl. Dept.), V. Pres. (1942-47); Lerke & Whortan, Assoc. Consultant (1939-41); British-American Oil Prod. Co., Div. Geol. (1938-39); Shell Petrol. Corp., Geol., Asst. to V. Pres. Expl. (1935-38); KS Emergency Relief Comm., Geol. (1934). Mem. Am. Assn. Adv. Sci. (Fellow), Geol. Soc. Am. (Fellow), Am. Assn. Petrol. Geol. (Hon. Mem., Nat. Gases of No. Am. [ed.] 1968, Dist. Lecturer 1969-70, V. Pres. 1960), OK Geol. Soc. (Hon. Mem.), Rocky Mtn. Assn. Geol., Hon. Mem., Am. Arbitration Assn., Am. Gas Assn., Assn. Prof. Geol. Sci., KS Geol. Soc., Oklahoma City Geol. Soc., Soc. Expl. Geophysicists, Soc. Ind. Prof. Earth Sci., Soc. Petrol. Engr., Rocky Mtn. Nat. Gas Men's Assn., PGC Hon. Tech. Adv.

****BENDLER, E. Perry (12):** Supr., Geol., Geol. & Land Serv., The East Ohio Gas Co., Cleveland, OH (1955-). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol. (Cert. #2473), No. OH Geol. Soc., OH Geol. Soc., OH Oil & Gas Assn., PGC Tech. Adv., Atlantic Area Comm.

BENNETT, William E. (12): Pres., Gasamex Ltd./W. E. Bennett Inc., Charleston, WV (1984-); Phoenix Hydrocarbon, Ltd., Pres. (1979-82); Monitor Petrol. Corp., V. Pres.-Expl., NYC, Charleston, WV (1976-82); Geol./Geophysicist (1974-76); Monitor Res. Corp., NYC Consultant (1976-82); United Fuel Gas Co., Sr. Geophysicist (1969-74); Geophys. (1962-68); Geol. (1957-61). Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Sci. (Cert. #1642, Past Pres. WV Sec.), Soc. Expl.

Geophysicists, Ind. Oil & Gas Assn. WV, Appalachian Geol. Soc., Fed. Power Comm. Nat. Gas Surv. (Tech. Adv. 1975-76), Am. Gas Assn. (Atl. Action Comm. 1974-75), Cert. Prof. Geol. VA (#6), PGC Tech. Adv., Atlantic Area Comm.

BLANCHARD, Louis A. (1): Sr. Petrol. Engr., Reservoir Engr., Panhandle Eastern Pipe Line, Co., Houston, TX (1968-). Mem. Am. Inst. Min. Met. & Petrol. Engr., Reg. Prof. Engr. TX, PGC Mid Continent Area Comm.

BOYD, Ellis R. Jr. (4): Supr. Petrol. Engr., Office of Oil & Gas, Div. of Reserves & Nat. Gas, DOE/EIA, Chief, Reserves and Prod. Branch Dep. Dir., Office of Oil & Gas Information System, Washington, DC (1977-); Fed. Power Comm., held var. pos. Area Rate Div. incl. Deputy Dir., Plan. & Dev. Div.; Bur. of Nat. Gas, Chief, Plan. & Spec. Proj. Branch; Marathon Oil Co., var. prod. engr., supr. posts, Gulf Coast Area (1954-66). Mem. Soc. Petrol. Engr., PGC Observer - EIA.

BRAMMELL, Charles R. (6): Mgr. Dev. Geol., Odeco Oil & Gas Co., New Orleans, LA (1984-); Graham Energy, V. Pres. Dev., Metairie, LA (1981-84); Consulting Dev. Geol. (1980-81); CNG Producing Co., Mgr. Dev. (1980); Chief Dev. Geol. (1977-80); Dev. Geol., New Orleans, LA (1973-77); Gulf Oil Corp., Expl. & Dev. Geol. (1960-73) and (1957-58); Sinclair Oil & Gas, Expl. & Dev. Geol. (1959-60); Hycalog, Mudlogging Engr. (1958-59). Mem. New Orleans Geol. Soc., PGC Tech. Adv., Gulf Coast Area Comm.

BRANDENBURG, Charles F. (1): Gas Research Institute, Chicago, IL. PGC Coalbed Methane Area Comm.

BROWN, Billy D. (5): Mgr., Res. Engr. Dept., Lone Star Gas Co., Dallas, TX (1982-), Sr. Staff Petrol. Engr. (1974-82); Eppler, Guerin & Turner, Acct. Exec. (1967-74); Cornell Oil Co., Petrol. Engr. (1966-67); TX Pacific Oil Co., Staff Petrol. Engr. (1962-66); TX Pacific Coal & Oil Co., Petrol. Engr. (1953-62). Mem. Am. Assn. Petrol. Geol., Nat. Gas Soc. No. TX, Soc. Petrol. Engr. of Am. Inst. Min., Met. & Petrol. Engr., PGC Bd. Dir., Mem. at Large, Tech Adv., Mid-Continent Area Comm.

* Pipelines representative.

** Gas distributors representative.

BROWN, Porter J. (7): Consultant, Charleston, WV (1985-); Columbia Gas Trans. Corp., Chief, Geol. Serv., Charleston, WV (1973-85); United Fuel Gas Co., Chief Geol. (1960-73); Geol. (1957-60); Asst. Geol. (1950-57). Mem. Am. Assn. Petrol. Geol., Geol. Soc. Am., Appalachian Geol. Soc., Geol. Soc. KY, Geol. Soc. OH, Geol. Soc. PA, Assn. Prof. Geol. Sci. (Cert. #2463), Gas Res. Inst. (Indus. Tech. Adv. Comm., Unconventional Nat. Gas), Prof. Geol. VA (#10), Prof. Petrol. Engr. (KY #4927), Prof. Oil & Gas Engr. WV (#5118), PGC Hon. Tech. Adv., Atlantic Area Comm.

BUCKNER, Duane (1): Consulting Geol., Monument, CO. PGC Rocky Mtn. Area Comm.

BUDZIK, Philip M. (2): Dir. Res. & Anal., Nat. Gas Supply Assn., Washington, DC. Mem. of Am. Assn. Adv. Sci., Int'l Assn. Energy Econ., PGC Observer - NGSa.

BULGER, John S. (3): Dir. Energy Res., Gaz Metropolitan, Inc., Montreal, Canada. PGC Observer - Canada.

BURGESS, Richard J. (10): Pres., No. Mich. Expl. Co., Jackson, MI (1981-); Exec. V. Pres. (1980-81), V. Pres. (1967-80); Consumers Power Co., Exec. Dir. Expl. (1967-80), Expl. Supr. (1963-67); Panhandle Eastern Pipe Line Co., Geol. (1962); Plymouth Oil Co., Geol. (1960-61); Imperial Oil Ltd., Canada, Geol. (1954-60). Mem. Am. Assn. Petrol. Geol. (CPG #462), Geol. Soc. Am., MI Oil & Gas Assn., MI Basin Geol. Soc., Ontario Petrol. Inst., PGC Pres./Gen. Chmn., Exec. Bd., Bd. Dir., Time & Site Comm. (ex officio), Comm. Def. & Proc. (ex officio), Tech. Adv., North Central Area Comm.

CANICH, Michael R., Jr. (1): Sr. Geol., Reg. Geol., Cabot Oil & Gas Corp., Pittsburgh, PA (1980-); Geol., Charleston, WV (1978-80); The Superior Oil Co., Geol., Houston, TX (1976-78). Mem. Am. Assn. Prof. Geol., Geol. Soc. Am., Soc. Econ. Paleo. & Min., Pittsburgh Assn. Petrol. Geol., PGC Atlantic Area Comm.

CHRISMAN, Louie P. (3): Mgr., Area Geol., ANR Pipeline Co., Houston, TX (1980-); Exxon Corp. (Humble Oil & Ref. Co.), Supr. Geol., Lafayette, LA (1965-73), Dist. Prod. Geol., Fort Smith, AR (1962-65), Dist. Prod. Geol., Great Bend, KS (1959-62); Exxon

Corp. (The Carter Oil Co.), Expl. Geol., Wichita, KS (1958-59), Expl. Geol., Ponca City, OK (1956-58), Jr. Geol., Wichita, KS (1952). Mem. Am. Assn. Petrol. Geol., PGC Mid-Continent Area Comm.

COOK, Billy C. (7): Thomson-Monteith, Dallas, TX (1984-); Holly Energy, Inc., Chief Geol., New Orleans, LA (1981-84); The LA Land and Expl. Co., Geol., New Orleans, LA (1972-81); Chevron Oil Co., Dev. & Expl. Geol. (1967-72). Mem. Am. Assn. Petrol. Geol., MS Geol. Soc., New Orleans Geol. Soc., Soc. Econ. Paleon. & Min., PGC Tech. Adv.

CROUCH, Marshall C. III (3): Pres., White Eagle Expl. Inc., Lakewood, CO (1980-); Oil & Gas Consultant, Lakewood, CO (1974-80); KS, NE Nat. Gas Co., Chief Geol. (organized Expl. Dept.), Lakewood, CO (1972-74); Cardinal Petrol., Expl. Geol., Denver, CO (1971-72); Plains Expl. Co., Expl. Geol., Denver, CO (1967-68), Geol. Asst. (1964-67). Mem. Am. Assn. Petrol. Geol., Soc. Ind. Prof. Earth Sci., Soc. Petrol. Engr., Am. Inst. Min., Met. & Petrol. Engr., Soc. Econ. Paleon. & Min., Rocky Mtn. Assn. Geol., WY Geol. Assn., KS Geol. Soc., PGC V. Chmn. Rocky Mtn. Area Comm.

CROWLEY, Charles J. (8): Retired, El Paso, TX (1984-); El Paso Nat. Gas Co., Consulting Reservoir Geol. (1977-84); Sr. Reservoir Geol. (1965-77); Hercules Powder Co., Supr. (1962-65); Consultant, WY, AZ (1958-62); Forest Oil Corp., Area Geol. (1953-59); Marathon Oil Co. (OH Oil), Scout-Area Geol., Billings, Casper (1949-53). Mem. Am. Assn. Petrol. Geol., El Paso Geol. Soc., PGC Hon. Tech. Adv.

CURRY, James K. (12): Geol. Consultant, Englewood, CO (1981-); Panhandle Eastern Pipe Line Co., Mgr. Rocky Mtn. Region, Denver, CO (1975-81); Pan Eastern Expl., Mgr. Expl. & Prod., Houston, TX (1973-75); Mgr. Expl., Mgr. Geol., Dist. Geol., Geol., Jr. Geol., Liberal, KS (1946-72). Mem. Am. Assn. Petrol. Geol., Soc. Petrol. Engr., Rocky Mtn. Assn. Geol., Am. Inst. Prof. Geol., PGC Hon. Tech. Adv.

D'ANDREA, Lucio A. (8): Chief, Gas Sect., Econ. Comm. for Europe, Geneva, Switzerland (1986-); DOE/EIA, Div. of Res. & Nat. Gas, Washington, DC. Exp. 30 yrs. in var. aspects, activities of nat. gas ind.: prod., trans., dist. and alt. gas supplies. Mem. Soc. Petrol. Engr., Int'l Assn. of Energy Econ., Soc. Mil. Engr., PGC Observer - ECE.

DARSEY, Donovan W. (3): Gen. Mgr., Res. Eval., MidCon Services Corp. (1986-); Nat. Gas Pipeline Co. of Am., Dir. Res. Eval., Houston, TX (1982-86), Mgr., Res. Engr. (1980-82), Chief Res. Engr. (1978-80), Div. Res. Engr. (1968-78), Dist. Res. Engr., Sr. Res. Engr., Res. Engr. (1965-68); Coastal States Gas Prod. Co., Res. Engr. (1963-65); Western Nat. Gas Co., Petrol. Res. Engr. (1960-63); Continental Oil Co., Assoc. Engr., Eunice, NM (1960); U.S. Air Force, Dreux, France (1957-59); Continental Oil Co., Engr. Trainee, Fort Worth, TX (1955-57). Mem. Am. Gas Assn. (Comm. Nat. Gas Res.), Soc. Petrol. Engr., Nat. Gas Men of Houston, Reg. Prof. Engr. TX, PGC Gulf Coast Area Comm.

DeBUSSCHERE, Gerard (2): Sr. Geol., Sun Expl. & Prod. Co., Dallas, TX (1983-), Geol. (1982-83); ANR Storage Co., Sr. Geol., Detroit, MI (1980-81); MI Consol. Gas Co., Geol., Detroit, MI (1977-79); Geol. Dept., Schoolcraft Community Coll., Instr., Livonia, MI (1975-76). Mem. Am. Assn. Petrol. Geol., Soc. Econ. Paleon. Min., Soc. Prof. Well Log Analysts, MI Basin Geol. Soc., Dallas Geol. Soc., PGC North Central Area Comm.

DECKER, A. David (1): Geol. Resource Enterprises, Inc., Grand Junction, CO. PGC Coalbed Methane Area Comm.

DERRICK, A. M., Jr. (12): Consulting Engr., El Paso, TX (1986-); El Paso Nat. Gas Co., Sr. V. Pres., Gov't and Public Affairs, Pub. Relations, El Paso, TX (1977-85), V. Pres., (1972-77), Asst. V. Pres. (1966-72), Mgr. Res. Engr. (1959-66), Asst. Mgr. Res. Engr., Houston, TX (1958-59), Sr. Res. Engr. (1953-57); Stanolind Oil & Gas Co., Res. Engr. Supr. Midland, TX (1951-53), Jr. Petrol. Engr. Wink, TX (1950-51), Tulsa, OK (1949-50), Pampa, TX (1947-48). Mem. Am. Assn. Petrol. Geol., Am. Inst. Min., Met. & Petrol. Engr., Soc. Petrol. Engr. (Comm. Nat. Gas Reserves, Tech. Dir.), Soc. Petrol. Eval. Engr., PGC Bd. Dir., CONGR Liaison, Hon. Tech. Adv., Edit. Comm., Comm. Def. & Proc.

DIMELOW, Thomas (1): V. Pres. Expl. & Dev., CNG Dev. Co., Pittsburgh, PA (1988-), Tulsa, OK (1986-88); Coseka Res. (USA) Ltd., V. Pres. Expl., Denver, CO (1981-86); Amoco Prod. Co., Mgmt. pos., Ft.

Worth, Houston, Chicago, Denver (1968-81). Mem. Am. Assn. of Petrol. Geol., Rocky Mtn. Assn. of Geol., Pittsburgh Assn. Petrol. Geol., PGC Atlantic Area Comm.

DONLON, Thomas J. (1): Expl. Grp. Supr., Amoco Prod. Co., New Orleans, LA (1987-), Geol., Field Studies & Expl., New Orleans, LA (1979-86), Texaco, Geol., Belaire, TX (1978-79). Mem. Am. Assn. Petrol. Geol., PGC Gulf Coast Area Comm.

DOWD, W. Timothy (6): Exec. Dir., Interstate Oil Compact Comm., Oklahoma City, OK. Involvement in var. gov't. act. as obs. or part., incl. OK House of Rep., counsel to the Gov. of OK. Mem. Am. Bar Assn., OK Bar Assn., Fed. Energy Bar Assn., PGC Observer - IOCC.

DREYFUS, Daniel A. (3): V. Pres., Strat. Anal. & Energy Forecasting, Gas Research Institute, Washington, DC (1981-). Mem. Am. Soc. Civil Engr., Soc. Am. Military Engr., Soc. Prof. Engr., Am. Political Sci. Assn., Am. Soc. Public Admin., PGC Observer - GRI.

DRUMHELLER, Richard. (1): Dev. Geol., Alaska Reg., Marathon Oil Co., Anchorage, AK. PGC Alaska Comm.

DWIGHT, Kenneth H. (2): Consulting Res. Engr., Sr. Res. Engr., Res. Engr., Gas Supply & Eval. Dept., El Paso Nat. Gas Co., El Paso, TX (1979-); Phelps-Dodge Copper Refinery Inc., El Paso, TX (1973-1979). Mem. Am. Inst. Met., Min. & Petrol. Engr. (Bd. Dir. 1980-86), El Paso Geol. Soc., WY Geol., Assoc., Reg. Engr. TX (#59369), PGC Mid-Continent Area Comm.

EDMONDSON, William F. (11): Consulting Geol., Bakersfield, CA (1980-); Mariposa Petrol. Co., V. Pres., Bakersfield, (1976-80); Westates Petrol. Co., Geol. (1975); Consultant, Sacramento Valley (1959-74); Superior Oil Co., Geol. (1952-59). Mem. Am. Assn. Petrol. Geol., San Joaquin Geol. Soc., PGC Tech. Adv., Pacific Area Comm.

FINNEY, Joseph J. (2): Assoc. Dir., Potential Gas Agency, CO Sch. of Mines, Golden, CO (1986-); Geol. Dept. Head (1975-85), Geol. Dept. Prof. (1974-75), Assoc. Prof. (1968-1974), Asst. Prof. (1962-68). Mem. Soc. Min. Engr., Min. Soc. Great Britain, Min. Assoc. Canada, Min. Soc. America (Fellow-MSA, 1971), PGC Assoc. Dir.

* Pipelines representative.

** Gas distributors representative.

FISCHER, David (2): Subsurface Geol., ND State Geol. Surv., Grand Forks, ND (1983-); Supron Energy Corp., Staff Geol., Denver, CO (1981-83); Gulf Oil Corp., Expl. Geol., Casper, WY (1980-81). Mem. Am. Assn. Petrol. Geol., PGC Rocky Mtn. Area Comm.

FISHER, C. Keith (7): Consulting Geol., Denver, CO (1981-); Panhandle Eastern Pipe Line Co., Reg. Geol./Chief Geol. (1977-81); U.S. Geol. Surv., Geol. (1974-77); Indep. Geol. (1973-74); American Stratigraphic Co., Gen. Mgr., V. Pres. (1961-73), Mgr., Billings, MT, Casper, WY (1955-61); Canadian Stratigraphic Serv., Ltd., Geol., Calgary, (1952-55); Panhandle Eastern Pipe Line Co., Geol., Liberal, KS (1949-52). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol., Soc. Ind. Prof. Earth Sci., Rocky Mtn. Assn. Geol., WY Geol. Assn., PGC Rocky Mtn. Area Comm.

*FOLEY, DWAYNE L. (3): Pres., OR Nat. Gas Dev. Corp. (1987-); NW Nat. Gas Co., V. Pres., Gas Supply & Pipeline Relations, Portland, OR (1985-), Dir., Gas Purchases, Pipeline Relations (1984-85), Mgr. Gas Supply Dept (1982), Supt. Gas Supply Comm. (1981), Supr. Engr. (1974), Leakage Control Supr. (1971-74), Asst. Corrosion Engr. (1968-71), Staff Engr. (1967). Mem. GRI Ind. Tech. Advis. Comm., Portland Chmbr Comm., Assn of NW Gas Utilities (Past Chmn., Gas Supply Comm.) Nat'l Assn. of Corrosion Engr. (Past Chmn.), NW Electrolysis Coord. Cncl. (Past Chmn), PCGA Gas Supply Comm. (Past Chmn.), Prof. Engr. of OR (NSPE), Columbia Chapter (Past Pres.), PGC Pacific Area Comm.

FOREMAN, Neil E., Sr. (1): Sr. Geol., Adv. Expl., Conoco, Inc., Houston, TX (1982-), Res. Geol., Expl. Res., Ponca City, OK (1974-82); Hazen Research, Geol./Geochemist, Golden, CO (1972-73). Mem. Min. Soc. of Am., Am. Soc. of Photogrammetry & Remote Sensing, PGC Atlantic Area Comm., Gulf Coast Area Comm.

GALLAGHER, Robert W. (9): Consultant, Sugarland, TX (1981-); So. Nat. Gas Co., Mgr., Reserves and Deliverability, Houston, TX (1967-81), Sr. Engr. (1962-67). Mem. Am. Assn. Petrol. Geol., PGC Tech. Adv.

GARSDIE, Larry J. (7): Acting Assoc. Dir., NV Bur. of Mines and Geol., Mackay School of Mines, Univ. of Nevada, Reno, NV (1987-), Chief Geol. (1985-87), Res. Geol. (1968-1985), Research Asst. (1965-67). NV Oil and Gas Conservation Comm. (Exec Sec. 1974-75),

Mem. Am. Assn. Petrol. Geol. (Mem. Energy Res. Div.), Geol. Soc. Am. (Fellow), Geol. Soc. NV (Sec.-Treas. 1969-70, Pres. 1973-74), Geothermal Res. Council, NV Petrol. Soc. (Treas. 1986), Soc. Econ. Geol., PGC Pacific Area Comm.

GERHARD, Lee C. (4): Dir., KS Geol. Surv., Univ of KS, Lawrence, KS; Prof. Geol., CO Sch. of Mines, Golden, CO; Consultant, Gerhard and Associates (1982-); Supron Energy Corp., Expl. Mgr., Englewood, CO (1981-82); ND Geol. Surv., State Geol., Dir. (1977-81), Asst. State Geol. (1975-77); Univ. ND, Chmn., Prof. Geol. (1977-81), Assoc. Prof. Geol. (1975-77); West Indies Lab, Fairleigh Dickinson Univ., Act. Dir., Assoc. Prof. Geol. (1975), Asst. Dir., Assoc. Prof. (1971-75), Univ. So. CO, Assoc. Prof. Geol. (1966-72); Sinclair Oil and Gas Co., Reg. Stratigrapher (1965-66), Expl. Geol. (1964-65); Amerada Petrol. Corp., Party Chief (1962); Univ. KS, Instr. Geol., Asst. Instr. Geol., Teaching Fellow (1960-64). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol., Assn. Am. State Geol., CO Sci. Soc., Geol. Soc. Am., ND Geol. Soc., Rocky Mtn. Assn. Geol., Soc. Econ. Paleon. & Min., PGC Rocky Mtn. Area Comm.

GILBERT, Maurice A. (3): Dir, Gulf Coast Area, ENRON Corp., Houston, TX (1987-), Staff Res. Engr., Tulsa, OK, Houston, TX (1984-87); No. Nat. Gas Co., Res. Engr., Tulsa, OK (1980-84); No. Minerals Div., Geol., Craig, CO (1979-80), Assoc. Geol., Billings, MT (1976-79). Mem., Am. Assn. Petrol. Geol., Soc. Petrol. Engr., Am. Inst. Min., Met. & Petrol. Engr., Houston Geol. Soc., PGC Gulf Coast Area Comm.

GROW, George C. Jr. (12): Consulting Geol., Westfield, NJ (1974-); Transcont. Gas Pipe Line Corp., Chief Geol.-Eastern Area, NJ (1950-73); The Peoples Nat. Gas Co., Jr. Geol. to Chief Geol., PA (1939-50); Standard Oil Co. NJ, Geol., Venezuela, (1938-39). Mem. Am. Assn. Petrol. Geol. (Cert. #31, Treas. 1974-76, Adv. Council 1976, Fndn. Dev. Coord. 1974-79), Am. Inst. Min., Met. & Petrol. Engr., Am. Inst. Prof. Geol. (Cert. #1774), Geol. Soc. Am. (Fellow), Soc. Indep. Prof. Earth Sci. (Cert. #1079), Pittsburgh Geol. Soc. (Past Pres.), Am. Gas Assn. (Comm. Underground Storage 1951-73, Chmn. 1960-61, Task Group on Gas Storage Stat., Chmn. 1964-71), PA Oil & Gas Assn., Ind. Oil & Gas Assn. WV, Lamont-Doherty Geol. Observatory, Columbia Univ. (Adv. Council), Fed. Power Comm. Nat. Gas Surv. (Underground Storage Task

Force 1972-73, Prosp. Expl. & Dev. Task Force 1975-78), PGC Bd. Dir. (Chmn. ex officio), Chmn. Atlantic Area Comm. (ex officio), Edit. Comm. (ex officio), Hon. Tech. Adv., Atlantic Area Comm.

HABBIT, Robert D. (8): Habbit Ent., Inc., El Paso, TX (1983-); El Paso Nat. Gas Co., Mgr. Reservoir Engr., El Paso, TX (1978-83), Mgr. Reservoir Studies (1978), Consulting Reservoir Geol. (1977-78), Staff Geol. (1966-77); Ind. Geol., Houston, TX (1965-66); El Paso Nat. Gas Co., Sr. Reservoir Geol., Houston (1957-65); Sohio Petrol. Co., Geophysicist/Geol., Gulf Coast-Rocky Mtn. (1954-57). Mem. Am. Assn. Petrol. Geol. (CPG #166), Am. Inst. Prof. Geol. (Cert. #2489), Am. Inst. Min., Met. & Petrol. Engr., Soc. Expl. Geophys., Rocky Mtn. Assn. Geol., El Paso Geol. Soc., PGC Bd. Dir., V. Pres. Western Region.

HAGEN, E. Bruce (6): Chmn., Comm., ND Public Service Comm., Bismarck, ND (1961-); Deputy Mtr. Veh. Reg. for ND (1961); Farmer, Benson, Ramsey Counties, ND (1956-). Mem. Fed. Commun. Comm. (Alaskan Joint Bd., Uniform Syst. of Accts. Joint Bd.), Mid-America Reg. Comm., Natl. Assn. Reg. Util. Comm. (NARUC) (Mem. Exec. Comm., Past Chmn., Commun. Comm., Pres. 1988), Reg. Energy Adv. Bd. U.S. Dept. of Energy, Reg. Cncl., State Intermodal Trans. Team (Chmn. 1977-80; 1985), Western Gov. Assn. Econ. Res. Ctr. Task Force. Served on Adv. Cncl. for State Reg. Commun. Study Proj., Mem. ND Res. Cncl. Chmn. Steering Comm. Trans. ND Econ. Dev. Roundtable, awarded ND Nat'l Leadership Award in recognition of pos. as Pres. of NARUC, PGC Observer - NARUC.

HALLINGER, Donald E. (11): Mgr., Spec. Proj., So. Calif. Gas Co., Los Angeles, CA. (1987-); Univ. of So. CA, Lecturer Geol. Sci. (1987-); Univ. of CA, LA, Lect. Space Planetary Sciences (1987-); Pacific Interstate & Pacific Lighting Gas Dev. Co., Reg. Mgr. Expl., Los Angeles, CA (1977-87), Sr. Geol. (1966-77). Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Sci. (Cert. #1865, Past Sec.-Treas.), Geol. Soc. Am., Soc. Econ. Paleon. & Min., Soc. Prof. Well Log Analysts, Reg. State of CA (#553), PGC Tech. Adv., Def. & Proc. Comm.

HANLEY, John M. (10): Consulting Engr., Omaha, NE (1973-); No. Nat. Gas Co., V. Pres. Gas Supply Studies (1965-73), V. Pres. Long Range Plan. (1963-65), V. Pres. Gas Supply (1950-63), Supt. Prod./Head Dept. (1942-50), Prod. Engr. (1936-42), Gas Field Supt., KS (1933-36). Mem. Soc. Petrol. Engr., Am. Gas Assn. (Nat. Gas Reserves Comm. 1945-56; Chmn. Nat. Gas Prod. Comm. 1956), Nat'l. Petrol. Cncl. (Comm. on U.S. Energy Outlook 1970-72), Fed. Power Comm. (Nat. Gas Surv., Gas Supply Task Force 1970-73), Adv. Comm. on Energy to Sec. of Int. 1970-71, PGC Hon. Tech. Adv.

HANSON, William B. (2): Geol. Assoc., Amoco Prod. Co., Denver, CO (1983-); Chris Craft Oil Co., Chief Geol., Denver, CO (1982-83); Davis Oil Co., Geol., Denver, CO (1981-82); Amoco Prod. Co., Proj. Geol., Denver, CO (1975-81); OR State Univ., Teaching Asst., Corvallis, OR (1974-75); U.S. Geol. Surv., Geol., Lakewood, CO (1971); Hydrologic Field Asst., Portland, OR (1968). Mem. Am. Assn. Petrol. Geol., Soc. Econ. Paleon. & Min., Rocky Mtn. Assn. Geol., WY Geol. Assn., PGC Rocky Mtn. Area Comm.

HARTMAN, Donald C. (8): Expl. Geol., Texaco Inc., Anchorage, AK (1985-), Land Rep., (1978-85); AK Geol. Surv., State Geol. (1973-74), Petrol. Geol. (1971-73); Texaco U.S.A., Geol., Anchorage, AK (1962-71), Geol., Los Angeles & Ventura Basins (1956-62). Mem. AK Assn. Petrol. Landmen, AK Geol. Soc., Am. Assn. Petrol. Geol., Anchorage Oil Scouts Assn., PGC Chmn. Alaska Area Comm.

HAUN, John D. (11): Consultant, Barlow and Haun, Inc. (1957-); Prof. Emer., CO School of Mines, Golden, CO (1985-); Prof. Petrol. Geol. (1955-85); Petrol. Res. Corp., V. Pres. (1952-57); Stanolind (Amoco), Geol. Party Chief (1951-52). Mem. Am. Assn. Petrol. Geol. (Pres. 1979-80), Am. Geol. Inst. (V. Pres. 1980-81, Pres. 1981-82), Am. Inst. Prof. Geol. (Pres. 1976), Geol. Soc. Am. (Fellow), Nat'l Petrol. Cncl., Rocky Mtn. Assn. Geol. (Pres. 1968), Soc. Econ. Paleon. & Min., Commissioner, CO Oil and Gas Conservation Comm. (1977-87, Chmn. 1985-87), PGC Tech. Adv., Chmn. Comm. on Def. & Proc., Rocky Mtn. Area Comm.

* Pipelines representative.

** Gas distributors representative.

HAWK, David H. (7): Dir., Energy Nat. Res., J. R. Simplot Co., Boise, ID (1984-); Horn Res. Corp., Sr. V. Pres., Boise, ID (1981-84); Sundance Oil Co., V. Pres. Expl., Denver, CO (1980-81); IGC Prod. Co., V. Pres., Gen. Mgr., Intermtn. Gas Co., Mgr. Expl. & Prod., Boise, ID (1977-80); Nat. Res. Advisor (1973-76); Tenneco Oil Co., Expl. Geol., Denver, CO (1972-73); Atlantic Richfield, Expl. Geol., Dallas, TX, Lafayette, LA (1970-72); Lecturer at numerous nat'l energy symposia. Mem. Am. Assn. Petrol. Geol. (Energy Min. Div.), ID Assn. Prof. Geol., Geol. Soc. Am., Rocky Mtn. Assn. Geol., PGC Rocky Mtn. Area Comm.

HEIDER, Benjamin M. III, (1): Consulting Geol., Sanquine Ltd., Tulsa, OK (1988-); Dyco Petrol. Corp., V. Pres. Expl., Tulsa, OK (1982-88); Encino Co., Consulting Geol., Tulsa, OK (1981-82), Mid-Cont. Expl. Mgr. (1981), Prosp. Geol. (1977-1981), Geol. Asst. (1977), Dyco Petrol. Corp. (1977-81). Mem. Am. Assn. Prof. Geol., PGC Mid-Continent Area Comm.

HERRINGTON, J. C. (10): Consulting Geol., San Antonio, TX (1985-); ARCO Expl. Co., Mgr., Geol. Staff, Dallas, TX (1981-85), Mgr., Atlantic OCS Proj., Mgr. CO₂ Expl., Western Reg. (1978-80), Mgr. Expl., Permian Dist., Midland, TX (1973-78), Spec. Proj., Dist. Geol., Lafayette, LA (1971-73), Dist. Geol., Tyler, TX (1962-71), Dist. Geol., offshore Gulf of Mexico (1959-62), Area Geol., Dallas, TX (1959), Geol., Sr. Geol., So. LA (1953-58), Oil Scout, MS, AL (1952-53). Mem. Am. Assn. Petrol. Geol., Am. Petrol. Inst., Assn. Prof. Geol. Sci., PGC Chmn. Bd. Dir., Exec. Comm., Comm. Def. & Proc., Chmn. Time & Site Comm.

HERSH, Kenneth F. (3): Independent Consultant, Bakersfield, CA (1989-); No. MI Expl. Co., Dist. Expl. Mgr., Bakersfield, CA (1980-89); Occidental Expl. & Petrol. Co., Expl. Geol., Bakersfield, CA (1979-80); Husky Oil Co., Expl. & Dev. Geol., Santa Maria, CA (1977-79); Union Oil Co., Expl. & Dev. Geol., Bakersfield, CA (1973-77). Mem. Assn. Am. Petrol. Geol., Coastal Geol. Soc., San Joaquin Geol. Soc., No. CA Geol. Soc., Ind. Petrol. Assn. Am. (Reg. V. Pres. San Joaquin Valley), CA Reg. Geol. (#4247), CA St. Bd. Reg. Geol. Geophys. (Prof. Practices Comm.), PGC Pacific Area Comm.

HILL, Danny (2): V. Pres. Policy Anal., Interstate Nat. Gas Assn. Am., Washington, DC. PGC Observer. - INNGA.

HILLIS, Tommie C. (5): Gas Supply Branch, Office of Pipeline & Producer Reg., Federal Energy Reg. Comm., Washington, DC. PGC Observer - FERC.

HITE, David M. (5): Prov. Expl. Mgr., ARCO Expl. Co., Anchorage, AK (1984-); ARCO Oil & Gas Co., Dist. Geol., Anchorage (1979-84), Sr. Staff Geol., Dallas, TX (1977-79), Sr. Geol., Anchorage (1975-77), Sr. Res. Geol., Dallas (1970-74), Research Geol. (1967-70). Mem. AK Geol. Soc., PGC Alaska Area Comm.

HODGDEN, H. Jerry (2): Hodgden Oil Co., Denver, CO. PGC North Central Area Comm.

HODGE Robert E. (1): Pres., MidCon Services Corp., Houston, TX. PGC Bd. Dir., Representative, Pipeline.

HOLLAND, J. Read (1): Dir, Sch of Mines & Energy Dev., Univ. of AL, Tuscaloosa, AL. PGC Coalbed Methane Area Comm.

HOLLETT, Douglas W. (2): Supr., NW Area Expl., Marathon Oil Co., Houston, TX; Supr., Dist. Geol., Marathon Oil Co., Cody, WY. PGC Rocky Mtn. Area Comm.

HOWARD, Richard H. (6): Geol., Oil & Gas Sec., IL State Geol. Surv., Champaign, IL (1958-); Phillips Petrol. Co., Geol. (1957); U.S. Geol. Surv., CO Plateau Uranium Expl. Proj., Geol. (1954). Mem. Am. Assn. Petrol. Geol., IL Geol. Soc., PGC North Central Area Comm.

HOWES, Wallace A. (2): Pres. W. Howes & Assoc., Houston, TX (1987-); H. Zinder and Assoc., V. Pres., Houston, TX, Washington, DC (1985-87); San Antonio Nat. Gas Pipeline Co., Dir. Reservoir Eval., Amarillo, Houston, TX (1956-82); Panhandle Eastern Pipeline Co., Chief Reserves Engr., Liberal, KS, Kansas City, MO (1950-56); USNR, Lt. Commander, Pacific Theater (1941-46). Mem. Am. Gas Assn. (Comm. on Proved Gas Reserves, Mid-Cont. Subcomm., Chmn. Rocky Mtn. Subcomm. Expl. & Prod. Comm., Prog. Chmn.), Nat. Gas Men of Houston (Dir.), Am. Mgt. Assn., Am. Petrol. Inst., Reg. Engr. TX (#15549), Soc. Petrol. Engr. (Chmn. Panhandle Sect., Chmn. Gas Tech. Comm., V. Chmn. fall meeting Prog. Comm.), U.S. Off. Tech. Assess. Comm. PGC Tech. Adv.

HUMPHRIES, E. Floyd (12): Consultant, NAPECO Inc., Houston, TX (1981-), Asst. V. Pres. (1980-81); Nat. Gas Pipeline Co. Am., Mgr. Geol., Expl. & Contracted Supply, Houston, TX (1954-80) Claud B. Hamill, Ind. (1949-54); Tidewater Assoc. Oil Co. (1946-49). Mem. Am. Assn. Petrol. Geol. (CPG.), Houston Geol. Soc., PGC Bd. Dir., Mem. at Large, Hon. Tech. Adv.

HURLEY, Steve C. (1): Sr. V. Pres., ODECO Oil & Gas Co., New Orleans, LA (1987-), Gen. Mgr., Expl. (1984-1987), Expl. Mgr. (1981-84), Sr. Geol. (1979-81); Exxon Co., USA, Dev. Geol. (1977-79), Expl. Geol. (1975-77). Mem. Am. Assn. Petrol. Geol., Soc. Expl. Geophys., New Orleans Geol. Soc., PGC Gulf Coast Area Comm.

JENKINS, J. Scott (3): Dir., Reserves & Availability, ANR Pipeline Co., Houston, TX (1986-), Mgr., Gas Supply Geol., Mgr., Area Geol., Sr. Geol., Staff Geol., Geol. (1974-86). Mem. Am. Assn. Petrol. Geol. (CPG), Houston Geol. Soc., PGC Chmn. Gulf Coast Area Comm., Edit. Comm.

JOHNSON, Merlin A. (9): V. Pres. Expl., Dart Energy Corp., Mason, MI (1984-); MI WI Pipe Line Co., Dir., Res. Engr., Geol., Detroit, MI (1981-84); ANR Prod. Co., Mgr. NE Dist., Troy, MI (1980-81); Am. Nat. Gas Prod. Co., Detroit, MI (1978-80); MI Nat. Res., V. Pres. Opr., MI Basin (1976-78); MI Cons. Gas Co., Dir., Geol. Expl. & Gas Acq. (1964-78), Mgr. Geol. Dept., Grand Rapids, MI (1959-64); Gulf Oil Corp., Zone Geol., Staff Asst., Expl. Mgr., MI, IL, Anadarko Basins (1949-59). Mem. Am. Assn. Petrol. Geol., Assn. Prof. Geol. Sci. (Dir.), MI Oil & Gas Assn. (Chmn., Oil & Gas Adv. Bd.), PGC Tech. Adv., North Central Area Comm.

KAISER, James P. (2): Mgr. of Res., So. Nat. Gas Co., Birmingham, AL (1985-); Core Lab Inc., Dallas, TX (1984-85); Self employed, Tulsa, OK (1979-84); Hudson Consulting, Tulsa, OK (1974-79); So. Nat. Gas Co., Houston, TX (1972-74); Core Lab Inc., Dallas, TX (1969-72); Pan Am Petrol., Mid-Cont. (1966-69). Mem. Soc. Petrol. Engr., TX Prof. Engr., PGC Gulf Coast Area Comm., Coalbed Methane Area Comm.

KALISCH, Robert B. (7): Dir., Gas Supply and Statistics, American Gas Assn., Arlington, VA (1975-); U.S. Air Force, assign. incl. Off. Sci. Res., Sci. and Tech. Staff Off., Dir., Ionospheric Physics Lab (1951-75). Mem. Inst. Elec. & Electronics Engr., Res. Soc. Am., Prof. Engr. (MA), PGC Bd. Dir., Rep. AGA.

KELLER, Stanley J. (6): Dept. of Nat. Res., IN Geol. Surv., Bloomington, IN (1953-). Mem. Am. Assn. Petrol. Geol., Am. Petrol. Inst., IN-KY Geol. Soc., IN Geol. Soc., PGC North Central Area Comm.

KELLY, William W., Jr. (1): V. Pres., Expl., Penn-VA Res. Corp., Duffield, VA (1984-); Controlled Res. Oil & Gas, V. Pres. Oper., Arlington, VA (1979-84); VA Div. of Mines, State Oil & Gas Insp., Big Stone Gap, VA (1974-79); VA Div. of Mines, Geol., Big Stone Gap, VA (1973-74). Mem. VA Cert. Prof. Geol. (#534), Am. Assn. Petrol. Geol., Soc. Prof. Engr., Appalachian Geol. Soc., KY Oil & Gas Assn., VA Oil & Gas Assn., PGC Atlantic Area Comm.

KELSO, Bruce E. (1): Sr. Geol., ICF-Lewin Energy, Lakewood, CO (1987-); U. S. Geol. Surv., Geol., Denver, CO (1980-87). Mem. Am. Assn. Petrol. Geol., Soc. Prof. Engr., Rocky Mtn. Assn. Geol., Assn. Ground Water Sci. & Engr., PGC Coalbed Methane Area Comm., Coalbed Methane Forum Steering Comm.

KENT, Harry C. (7): Exec. Dir., Potential Gas Agency, CO School of Mines, Golden, CO (1976-), Prof. Geol. (1969-), Head Geol. Dept. (1970-75), Act. Head Geol. Dept. (1969-70), Assoc. Prof. Geol. (1967-69), Asst. Prof. Geol. (1964-67), Instr. Geol. (1956-64); The California Co., Geol., FL, LA (1953-56); Stanford Univ., Teaching Asst. (1953). Mem. Am. Assn. Petrol. Geol. (CPG #2485), Geol. Soc. Am. (Fellow), Rocky Mtn. Assn. Geol., Soc. Petrol. Engr., PGC Treas., Exec. Comm., Bd. Dir., Edit. Comm., Def. & Proc. Comm., Time & Site Comm.

KERNEN, Michael (3): Expl. Mgr., Noble Drilling Corp., Oklahoma City, OK (1984-); Samedan Oil Corp., Geol. (1980-84). Mack Oil Co., Geol., Duncan, OK (1976-80). Mem. Am. Assn. Petrol. Geol., Ardmore Geol. Soc., OK City Geol. Assn., So. OK Assn. Petrol. Landmen, Ind. Petrol. Assn. Am., PGC Mid-Continent Area Comm.

* Pipelines representative.

** Gas distributors representative.

KIDWAI, Moid U. (7): Staff Res. Engr., ENRON Corp., Houston, TX (1986-); No. Nat. Gas Co., Staff Res. Engr., Denver, CO (1981-86), Sr. Res. Engr., Denver, CO, Omaha, NE (1978-80), Res. Engr. (1975-77); Metro Subway, Geol., Washington, DC (1974-75); Oil & Gas Dev., Corp., Petrol. Engr., Pakistan, (1968-73). Mem. Am. Assn. Petrol. Geol., Soc. Petrol. Engr., PGC Rocky Mtn. Area Comm.

KNEBEL, Robert M. (2): Semi-Retired, Consultant, Grandbury, TX (1986-); Adler Petrol. Co., Pres., Irving, TX. (1977-86); Ensearch Expl. Inc. Wellsite, Distr. Sr., Chief Geol., Int'l. Expl. Mgr., Dist. Expl. Expedit. Mgr. (1977-79). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol., Dallas Geol. Soc., Ft. Worth Geol. Soc., PGC Mid-Continent Area Comm.

*KNOBLOCH, Mike H. (4): Mgr., Mid-Continent Reservoir Engr., Panhandle Eastern Pipeline Co., Houston, TX (1988-), Mgr., Forecasting & Oper. Div., Kansas City, MO (1985-1988), Mgr. Res. Engr. Div. (1984-85), Mgr., Prosp. Eval. (1981-84), Asst. Chief Res. Engr. (1976-81), Res. Engr., Liberal, KS (1971-76); Mobil Oil Corp., Field Engr., Countyline, OK, (1969). Mem. Am. Gas Assn. (Reserves Subcommittee), Soc. Petrol. Engr., PGC Chmn. Mid-Continent Area Comm., Edit. Comm.

KOTILOWSKI, Frank E. (6): Dir., Sr. Geol., NM Bureau of Mines & Min. Res., Socorro, NM (1974-), Assoc. Dir., Sr. Geol., Econ. Geol. (1951-74); IN Geol. Surv., Party Chief, Coal Div. (1947-51); IN Univ. Geol. Dept., Inst. (1950-51). Mem. Am. Assn. Petrol. Geol. (Editor 1971-75), Geol. Soc. Am. (Fellow), Soc. Econ. Geol., Assn. Am. State Geol. (Pres. 1985-86), Soc. Econ. Paleon. & Min., Assn. Prof. Geol. Sci. (Past Pres. NM Section), Am. Assn. Adv. Sci. (Fellow); PGC Rocky Mtn. Area Comm.

KUCEWICZ, John C. Jr. (4): Consultant, Mandeville, LA (1988-); CNG Prod. Co., Geol. Spec., Offshore Expl. & Field Stud., New Orleans, LA (1984-88), Geol. Spec., Dev. Geol., McAllen, TX (1981-84), Geol. Spec., New Orleans, LA (1978-81); Texaco Inc., Geol. Asst., New Orleans, LA (1975-78). Mem. Am. Assn. Petrol. Geol., Corpus Christi Geol. Soc., New Orleans Geol. Soc. (Past Chmn., Scouting Comm. 1978-81), A.G.W.S.E., PGC Tech. Adv., Gulf Coast Area Comm., Coalbed Methane Area Comm.

KUUSKRAA, Vello A. (1): Sr. V. Pres., ICF-Lewin Energy, Fairfax, VA (1970-); Fry Consultants, Inc., Proj. Mgr., Washington, D.C. (1968-70); Chevron, Inc., Fin. Anal., San Francisco, CA (1965-66); U.S. Army, Capt., Pentagon, DC (1966-68). Mem. Soc. Petrol. Engr., Wharton Club of Washington, DC, PGC Coalbed Methane Comm.

LANG, Robert V. (1): Coordinator, Res. Mgmt., Gulf Canada Res., Ltd., Calgary Alberta (1965-) Predecessory cos., Prod. Oper., Reservoir Engr., Reserves, Dev. Plan., Prop. Acq., Divest., Res. Mgmt. Mem. Can. Petrol. Assn. (Chmn. Res. Comm.), Petrol. Soc. of CIM., Assn. Prof. Engr., Geol. & Geophys. of Alberta, PGC Observer - Canada.

LATZ, John E. (2): Dep. Dir., Energy & Min. Res., Bur. of Land Mgmt., U.S. Dept. of the Interior, Washington, DC, PGC Observer - BLM.

LEEPER, Wayne S. (6): Geol., Expl. & Geol., Keystone Energy Oil & Gas, Inc., Pittsburgh, PA (1982-); National Fuel Gas Supply Corp., Chief Geol., Mgr. Expl. Buffalo, NY (1974-81); United Nat. Gas Co., The Sylvania Corp., Chief Geol., Oil City, PA (1969-74), Geol. (1961-69). Mem. Am. Assn. Petrol. Geol., Pittsburgh Geol. Soc., Pittsburgh Assn. Petrol. Geol., PA Oil & Gas Assn. (Bd. Dir. 1976-, Chmn. Gas Comm. 1983-), I.O.G.A. of NY (Bd. Dir. 1981-85, Sec. 1981, Treas. 1983), PGC Atlantic Area Comm.

LEWIS, Jack (1): Gen. Mgr. Expl. & Dev. Plan., Cons. Nat. Gas Co., Pittsburgh, PA (1984-); Patrick Petrol. Co., V. Pres. Expl., Jackson, MI (1977-84); Shell Oil Co., Staff, Dist. Geol. Onshore, Offshore Expl., New Orleans, LA (1968-77). PGC Bd. Dir., Mem. at Large.

LONDON, Larry F. (3): Pres., London Operating Co., Dallas, TX (1986-); London Petrol. Corp., Pres., Dallas, TX (1977-); Ensearch Expl., Dist. Petrol. Engr., Dallas, TX (1974-77); Texaco Inc., Petrol. Engr., Gainesville, TX (1970-74). Mem. Soc. Petrol. Engr., Dallas Geol. Soc., Dallas Prod. Club, TIPRO, Nat. Gas Soc. No. TX, Reg. Petrol. Engr., PGC Mid-Continent Area Comm.

LUDWICK, Lester E. (10): Retired, Consultant, El Paso, TX (1986-); El Paso Nat. Gas Co., Mgr. Res. Geol., Houston, El Paso, TX (1954-85); Standard Oil Co. of TX, Dev. Geol. (1950-54); Caran Bros. Engr. Co., Well Logging Engr. (1950). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol. (#6398), Soc. Petrol. Engr., Am. Gas Assn. (Nat. Gas Reserves Comm.), El Paso Geol. Soc., PGC Tech. Adv.

LUFT, Barry G. (3): V. Pres., Gas Supply, Western Gas Marketing Ltd., Calgary, Canada. PGC Observer - Canada.

LUKSCH, Jon H. (3): Geol., Denver, CO.; Texaco Inc. (formerly Getty Oil Co.), Expl. Geol., Bakersfield, CA (1983-); Getty Oil Co., Prod. Geol. (1980-83); Soils Int'l, Staff Geol., San Gabriel, CA (1979-80); Bechtold Satellite Tech., Asst. Geol., Industry, CA (1978-79). Mem. Am. Assn. Petrol. Geol., San Joaquin Geol. Soc., Soc. Econ. Paleon. & Min. (Pacific Sec.), PGC Pacific Area Comm.

*LUNDY, Curtis L. (9): Sr. Geol. Adv., MICHCON Gas Co., Detroit, MI (1985-), Mgr., Expl. (1983-85), Mgr., Geol., Storage Engr. (1981-83), Mgr. Geol. (1978-81); American Nat. Gas Co., Mgr. Storage Geol. (1974-78); MI Consolidated Gas Co., Expl. Geol. (1963-74); Humble Oil & Refining Co., Exploitation Geol. (1958-63). Mem. Am. Assn. Petrol. Geol. (CPG #713), MI Basin Geol. Soc., MI Oil & Gas Assn., Soc. Petrol. Engr., PGC Tech. Adv., North Central Area Comm.

LUTHY, Stephen T. (2): Sr. Geol., Chevron U.S.A. Inc., Hobbs, NM (1988-), Geol., Denver, CO (1985-88); Gulf Oil Corp., Geol., Casper, WY (1981-85); U.S. Geol. Surv., Geol., Denver, CO (1979-81). Mem. Am. Assn. Petrol. Geol., Geol. Soc. America, Rocky Mtn. Assn. Geol., PGC Rocky Mtn. Area Comm.

LYNCH, Roy W., Jr. (2): Dev. Geol., Cabot Oil & Gas Corp., Charleston, WV (1987-); Berea Oil & Gas Corp., Buffalo, NY (1983-86); TX Int'l Petrol., Charleston, WV (1980-83); Petrol. Dev. Corp., Bridgeport, WV (1977-1980). Mem. Am. Assn. Petrol. Geol., Geol. Soc. Am., PGC Atlantic Area Comm.

MACIEJ, Hans (2): V. Pres., Canadian Petrol. Assn., Calgary, Canada. PGC Observer - Canada.

* Pipelines representative.

** Gas distributors representative.

MAHER, John B. Jr. (3): Pres., Polaris Petrol. Ltd., Calgary, Canada. (1979-); Sceptre Res., Expl. Mgr., (1976-79); Amoco Canada, Expl. Geol. (1970-76). Mem. Am. Assn. Prof. Geol., Can. Soc. Prof. Geol., Assn. Prof. Eng'rs Geol. & Geophys. Alberta, G.S., C.W.L.S., PGC Observer - Canada.

**MANTEK, William E. (9): Sr. Staff Geol., No. MI Expl. Co., Jackson, MI (1976-); Consumers Power Co., Sr. Geol. (1965-76); MI Geol. Surv., Oil & Gas Sec., Geol., Lansing, MI (1956-65). Mem. Am. Assn. Petrol. Geol. (CPG #828), MI Basin Geol. Soc., PGC Bd. Dir., Chmn. Editorial Comm., Tech. Adv., North Central Area Comm.

MARCZYNSKI, Louis F. (4): Reservoir Engr. Supr., Mobil Expl. & Prod. U.S., Inc., Midland, TX (1985-); Superior Oil Co., Reservoir Engr. Supv., Midland, TX (1984-85), Exploitation Engr. Spec. (1982-84); No. Nat. Gas Co. (InterNorth), Reg. Mgr. Res. Eval., Midland, TX (1978-82); sixteen yrs. exp. var. engr. pos. (1966-82). Mem. Am. Gas Assn., Nat. Gas Soc. Permian Basin, Soc. Petrol. Engr., Am. Inst. Min. Met. & Petrol. Engr., PGC V. Chmn. Mid-Continent Area Comm.

MARNEY, Gordon (3): Ind. Consultant, (1988-); Total Petrol., Inc., Mgr. Geol., Gulf Coast Div., Houston, TX (1983-88); Energy Reserve Group; Canadian Expl. Mgr., Calgary, (1980-83); Amoco Prod. Co., Geol., Eastern, Western Canada, Res. Ctr., New Orleans, Trinidad (1970-80). Mem. Houston Geol. Soc., PGC V. Chmn. Gulf Coast Area Comm.

MARTCH, Henry B. Jr. (2): Dir., Res. Engr. Dept., El Paso Nat. Gas Co., El Paso, TX (1984-), Dir., Plan. (1982-84), Exec. Staff (1980-82), Chief Engr. (1977-80), Dir. Engr. Plan. (1975-77), Mgr. Engr. Systems (1973-75), Sr. Systems Engr. (1967-73). PGC Tech. Adv.

MARTIN, Paul E. (1): Chief, Offshore Res. Eval. Div., Minerals Mgmt. Svc./DOE, Reston, VA (1987-88), Chief, Branch of Offshore Res. Assess., Reston, VA (1985-87); U.S. Geol. Surv., Reg. Supr. Field Oper., Washington, DC (1981-84); Dist. Supr., So. Atl. (1978-80), Petrol. Engr., Reston, VA (1975-77) Petrol. Engr., New Orleans, LA (1972-75); Fed. Power Comm., Gen. Engr., Washington, DC (1970-71). PGC Observer - MMS.

McELROY, John H. (5): Sr. Prof. Petrol. Engr., Corp. Res. Grp., Texaco, Inc., Houston, TX (1989-), Sr. Coord., Expl. & Prod. Tech. Div. (1986-89), Sr. Coord., Expl. & Prod. Svc. Dept. (1977-86), Expl. Coord. (1972-77), Midland Asst. Div. Mgr. (1969-72), Houston Div. Geol. (1967-69), Houston Asst. Div. Geol. (1961-67), Geol. (1958-61); Seaboard Oil Co., Geol., Asst. Dist., Dist. Geol. (1951-58); Gulf Oil Corp., Surf. & Subsurf. Geol. (1948-51). Mem. Am. Assn. Petrol. Geol., Soc. Petrol. Engr., PGC Gulf Coast Area Comm.

MEISSNER, Fred F. (1): Bird Oil Corp., Denver, CO. PGC Coalbed Methane Area Comm.

MILLER, Marshall S. (2): Pres., Owner, Geological Consulting Svc., Inc., Bluefield, VA (1976-); Pocahontas Land Corp., Fuels Geol., Bluefield, VA (1974-1975); VA Div. of Min. Res., Fuels Geol., Charlottesville, VA (1969-1974); Schlumberger Well Services, Field Engr., Watseka, IL (1967-69). Mem. Am. Inst. Prof. Geol., Am. Assn. Petrol. Geol. (Energy Min. Div.), Soc. Petrol. Geol., Appalachian Geol. Soc., Am. Inst. Min. Engr., Sigma IX (WV Univ. Res. Hon.), Assn. Ground Water Sci. & Engr., PGC Atlantic Area Comm., Coalbed Methane Area Comm.

MILLER, Richard D. (3): Supr. Petrol. Engr., Chief, Sect. Helium Res. Eval., U.S. Bureau of Mines, Amarillo, TX (1981-), Supr., Helium Field Oper. (1958-81). Registered Prof. Engr., TX Reg. (#25064), PGC Observer - BUMINES.

MORRIS, Jeffery V. (8): Consultant, Houston, TX (1985-); Transco Energy Co., Mgr. Res. Geol., TGPL, Houston, TX; Reg. Geol., Dist. Geol., Sr. Geol., Geol. (1961-85); Sun Oil Co., Geol., Houston, TX (1959-61); El Paso Nat. Gas Co., Geol., New Orleans, LA (1956-59); Gulf Oil Corp., Geol., New Orleans, LA (1954). Mem. Am. Assn. Petrol. Geol., Houston Geol. Soc. (Pres. 1978-79), Nat. Gas Men of Houston, PGC Bd. Dir., V. Pres. Eastern Region.

MURDY, Richard J. (12): Retired, Lumberton, MS (1984-); CNG Producing Co., Pres., New Orleans, LA (1979-84), V. Pres., Clarksburg, WV (1973-1978); Consolidated Nat. Gas Co., Asst. to Chmn. of Bd. (1968-73), Asst. Treas., New York, NY (1963-68), Asst. to Pres. (1957-63); New York State Nat. Gas,

Chief Geol., Pittsburgh, PA (1952-1957); Consulting Gas Underground Storage Engr., Pittsburgh, PA (1948-52). Mem. Am. Assn. Petrol. Geol., Am. Gas Assn., Am. Inst. Petrol. Geol., Geol. Soc. Am., So. Gas Assn., Soc. Petrol. Engr., PGC Hon. Tech. Adv.

MURRAY, D. Keith (11): Consulting Geol., Lakewood, CO (1984-); Energetics, Inc., Chief Geol., Englewood, CO (1981-83); CO Sch. of Mines Res. Inst., Golden, CO (1979-81); CO Geol. Surv., Denver, CO (1973-79); Coronado Oil Co., Consulting Geol., Denver, CO (1969-73); Sinclair Oil Corp., Denver, CO (1966-69); Consulting Geol., Denver, CO (1962-66); Clark Oil & Ref. Corp., Denver, CO (1960-62); Ind. Geol., Los Angeles, CA (1959-60); Manabi Expl. Co., Ecuador, SA (1956-58); Shell Oil Co., CA, UT, NV, LA (1953-56). Mem. Am. Assn. Petrol. Geol. (Rocky Mtn Sec., Councillor, Pres. 1986-87, Energy Min. Div., House of Delegates, V. Pres. 1979-80), Am. Inst. Prof. Geol., CO Sci. Soc., Denver Coal Club, Geol. Soc. Am., Rocky Mtn Petrol. Pioneers, WY Geol. Assn., PGC Bd. Dir., Asst. V. Pres. Western Region, Chmn. Coalbed Methane Area Comm.

MYERS, Eugene (3): Dist. Dev. Geol., Union Oil Co. of CA, Lafayette, LA (1984-); Dev., Util. Geol. (1976-84), Dev. Geol., New Orleans, LA (1965-76); Pure Oil Co., Expl. Geol., Lafayette, LA (1962-65), New Orleans, LA (1957-62). Mem. Am. Assn. Petrol. Geol., Lafayette Geol. Soc., PGC Gulf Coast Area Comm.

NEUMEYER, Charles L. (9): Energy Consultant, Huntington, NY, Brooklyn, NY (1984-); The Brooklyn Union Gas Co., Sr. Off. Reg. Affairs & Supply Plan. Dept., Mktg. & Adv. Dept., Urban Affairs Dept., Corp. Commun. Sec., Gov. Affairs Sec., Expl. Act., Subs. Act. - FRI, GEI, MDC (1971-84), V. Pres., New Bus. Dept., Publ. Rel. & Adv. (1968-71), Rate Dept., Asst. V. Pres. (1962-68), Mgr. (1957-62), Asst. Mgr. (1954-57), Res. Asst. (1946-54), Acct. Dept., (1942), Cadet Engr. (1941). Mem. Assn. Gas Dist. (former Chmn., Exec. Comm., Mem. Prog. Rev. Comm., former Mem., Chmn. Nom. Comm.), Brooklyn Club, Gasmen's Roundtable, Interstate Nat. Gas Assn., Soc. Gas Lighting, former Mem. Am. Gas Assn. (Mem. Gas Supply Comm., Industry Commun. Comm. (former Mem., Chmn. Rate Comm.), PGC Hon. Tech. Adv., Edit. Comm.

NOWICKI, Mike (1): Mgr. Reservoir Engr., Gulf Coast Region, Panhandle Eastern Pipe Line Co. (Trunkline Gas Co.)(1988-); Trunkline Gas Co., Supr. Geol., Houston, TX (1985-88), Div. Geol., Houston, TX (1984-85) Geol., Houston, TX, (1980-84); U.S. Dept. of Energy, Phys. Sci., Washington, DC (1978-80). Mem. Am. Assn. Petrol. Geol., Soc. Petrol. Engr., Houston Geol. Soc., PGC Gulf Coast Area Comm.

O'SHEA, Patrick (2): Asst. Dir., Nat. Gas Supply, Gas Research Inst., Chicago, IL. PGC Observer - GRI.

PANKAU, Rick (2): Dir. of Res. Engr., Permian & Rocky Mtn. Region, ENRON Corp., Houston, TX.(1985-); No. Nat Gas Co., Dir. Res. Engr., Anadarko Deep Area, Tulsa, OK (1983-85), Engr. to Staff Engr., Tulsa, OK (1978-83). Mem. Soc. Petrol. Engr., Soc. Prof. Well Log Anal., PGC Mid-Continent Area Comm.

PEDIGO, Norris E. (3) Midcon Svcs. Corp., Houston, TX (1969-89), Mgr. Mid-Cont. Res. Engr., (1986-89), Nat. Gas Pipeline Co., Div. Reservoir Engr., Houston, TX (1972-86), Dist. Res. Engr. (1969-72), Dist. Res. Engr., Amarillo, TX (1967-69), Sr. Res. Engr. (1957-66), Dev. Engr., Chicago, IL, (1956-57), Meter Station Oper., Fairbanks, TX (1953-55). Mem. Am. Gas Assn. (Res. Subcomm.), Nat. Gas Men, Houston Soc. Petrol. Engr., Reg. Prof. Engr. TX, PGC Mid-Continent Area Comm.

**PERKINS, Kenneth R. (4): Mgr. Gas Supply, Cabot Transmission Corp., Houston, TX (1987-); Cabot Corp., Mgr. Gas Supply, Trans. Div., Amarillo, TX (1985-87), Sr. Gas Buyer, Trans. Div. (1984-85); Westar Transmission Co., Sr. Gas Contracts Rep., Amarillo, TX (1982-1984); Tejas Gas Corp., Dst. Mgr., TDX Offshore, Houston, TX (1981-1982); No. Nat. Gas Co., Sr. Gas Contracts Rep., Houston, TX (1978-1981); MI WI Pipeline Co., Staff Gas Contracts Rep., Houston, TX (1975-1978). Mem. Nat. Gas Men, Houston, Nat. Gas Soc. No. TX, Nat. Gas Soc., Permian Basin, Panhandle Nat. Gas Soc., PGC Mid-Continent Area Comm.

* Pipelines representative.

** Gas distributor representative.

*PETERS, Robert L. (2): Mgr. Res., Eastern Reg., Transcontinental Gas Pipeline Corp., Houston, TX. PGC Gulf Coast Area Comm.

PLATT, Jeremy (4): Sr. Proj. Mgr., Utility Plan. Methods Ctr., Electric Power Res. Inst., Palo Alto, CA (1974-). Mem. Am. Assn. Petrol. Geol. (Energy Minerals Div., Pres. 1988-89), Geol. Soc. Am., PGC Observer - EPRI.

POWERS, Richard B. (6): Geol., U.S. Geol. Surv., Br. Petrol. Geol., Lakewood, CO (1974-); Consultant, Denver, CO (1971-74); Bolyard & Assoc., V. Pres., Denver, CO (1968-71); Tenneco Oil, Sr. Staff Geol., Houston, TX (1967-68), Dist. Geol., Casper, WY (1965-67), Dist. Mgr., Pittsburgh, PA (1962-65), Reg. Geol., Casper, WY, Denver, CO (1959-62); Petrobras, Geol., Belem, Brazil (1958-59); Pure (Union) Oil Co., Geol., Grand Junction, CO (1952-58). Mem. Am. Assn. Petrol. Geol., Rocky Mtn. Assn. Geol., WY Geol. Assn., Canadian Soc. Petrol. Geol., PGC Rocky Mtn Area Comm.

PRITCHETT, Ron W. (2): Ind. Geol. Engr., Res. Projects, Englewood, CO (1984-); Eurafrepp, Inc., Proj. Geol., Denver, CO (1977-84); Sundance Oil, Oper. Geol., Denver, CO (1975-77); Cockrell Corp., Staff Geol., Denver, CO (1973-75); Viking Expl., Geotech, Denver, CO (1973); Summer field work, geotech, seismic crew, WY, mineral expl. surv., Arctic Islands (1968-72). Mem. Am. Assn. Petrol. Geol., Am. Inst. Geol., Rocky Mtn. Assn. Geol., Soc. Petrol. Engr., Soc. Ind. Prof. Earth Sci., PGC Rocky Mtn. Area Comm., Coalbed Methane Comm.

RASSINIER, Edgar, A. (12): Ind., Houston, TX (1982-); Trunkline Gas Co., Dir. Res. Plan., Houston, TX (1964-81), Chief Petrol. Engr. (1953-64); Phillips Petrol. Co., Supr. Petrol. Engr., Prod. Dept., Bartlesville, OK (1951-52), Reg. Reservoir Engr., Houston, TX (1947-50), Div. Reservoir Engr., Oklahoma City, OK (1946), Petrol. Engr., Bartlesville, Borger, Kansas City (1942-43). Mem. Am. Assn. Petrol. Geol., Am. Inst. Min., Met. & Petrol. Engr., Houston Engr. & Sci. Soc., Houston Geol. Soc., Reg. Prof. Engr. (TX), PGC Hon. Tech. Adv., Gulf Coast Area Comm.

RICE, Dudley D. (1): Res. Geol., U.S. Geol. Surv., Denver, CO (1973-). Mem. Am. Assn. Petrol. Geol., Canadian Soc. Petrol. Geol., Soc. Econ. Paleo. & Min., Rocky Mtn. Assn. Geol., PGC Observer - USGS.

****ROCHESTER, David A. (8):** Mgr., Gas Expl., Pub. Svc. Enterprise Grp., Gen. Mgr., Oper. Ofcr., Energy Dev. Corp. GASDEL Pipeline System, Inc. (1985-); Pub. Svc. Elec. & Gas Co., Asst. Mgr., Gas Supply, Newark, NJ (1981-85), Fuels Planning Engr. (1977-81), Nat. Gas Engr. (1971-77), Engr. (1967-71), Cadet Engr. (1966-67); River Gas Co., Engr., Marietta, OH (1964-66). Mem. Am. Gas Assn. (Tera Advisory Comm., Task Force), Am. Inst. Min., Met. & Petrol. Engr., Assoc. Gas Dist. (Chmn, Operating Comm.), Gas Dist. Info. Serv. Inc. (Off., Bd. Dir.), NJ Gas Assn. (Supply & Rates Comm.), Petrol. Expl. Soc. NY, Soc. Petrol. Engr., PGC Sec., Bd. Dir., Exec. Comm., Edit. Comm., Gulf Coast Area Comm

***ROTH, Scott A. (2):** Reservoir Geol. Supr., Transcont. Gas Pipe Line Corp., Houston, TX (1981-); Fed. Energy Reg. Comm., Geol., Washington, DC (1979-81). Mem. Am. Assn. Petrol. Geol., Soc. Econ. Paleon. & Min., Houston Geol. Soc., PGC Gulf Coast Area Comm.

SALA, Darrell L. (2): Principal Econ., Inst. of Gas Tech., Chicago, IL (1986-), Econ. (1984-86), Assoc. Econ. (1981-84), Asst. Econ. (1978-81). Mem. Int'l. Assoc. Energy Econ., PGC Observer - IGT.

SATTERFIELD, Ira R. (4): Geol., Chief of Oil & Gas/Subsurface Sect., MO Geol. Surv., Rolla, MO (1981-), Oil & Gas Geol. (1979-81), Stratigrapher, Areal Geol. (1967-79); Amoco Prod. Co., Expl. Geol. (1965-67). Mem. Am. Assn. Petrol. Geol., Assn. MO Geol., PGC North Central Area Comm.

***SEMETKO, Daniel M. (2):** Sr. Geol., Staff Geol., Geol., ANR Pipeline Co., Houston TX. (1979-). PGC Gulf Coast Area Comm.

SHERMAN, Carl W. (11): Retired, Univ. Park, PA (1985-); PA State Univ., Assoc. Prof. Petrol., Nat. Gas Engr., University Park, PA (1975-85); Honeoye Storage Corp., Mgr. Opr. (1974-75); NY State Public Serv. Comm., Prin. Systems Plan., Gas Div. (1971-74); NY State Div. Min. Res., Dir. (1964-71); IL Geol. Surv., Head Petrol. Engr. Sec. (1957-64); JB & M Inc., Tex-Canadian Oil Corp., Marathon, The California Co. (1948-57). Mem. Am. Gas Assn., Am. Petrol. Inst., Soc. Petrol. Engr., Interstate Oil Compact Comm., PGC Atlantic Area Comm.

SISSON, Alexander (8): Geol. Consultant, Anchorage, AK (1986-); Union Oil Co. of CA, Sr. Geol., Anchorage, AK (1966-86); Esso Standard Oil, Sr. Geol., Bogota (1964-66); Geol., Guatemala (1961-63); Geol., Havana (1957-60); Carter Oil Co., Geol., Denver (1951-56). Mem. Am. Assn. Petrol. Geol. (Environ. Comm.), AK Geol. Soc. (Pres. 1977), PGC Tech. Adv.

SONDEY, Edward J. (2): V. Pres., The Brooklyn Union Gas Co., Brooklyn, NY. PGC Tech. Adv.

STICKNEY, Roger. (1): Area Dev. Geol., UNOCAL Corp., Anchorage, AK. (1981-), Expl. Geol. (1976-81). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol., Soc. Prof. Well Log Anal., AK Well Log. Soc. (Past Pres., V. Pres.), AK Geol. Soc. (Pres.-Elect, Treas.), Geophys. Soc. of AK, PGC Alaska Comm.

***STOLLAR, Richard L. (3):** Chief. Geol., Columbia Nat. Res. Inc., Charleston, WV (1986-); Columbia Gas Trans. Corp., Supr. Geol. (1985-86), Sr. Geol. (1981-85), Geol. I (1979-81), Geol. (1976-79). Mem. Am. Assn. Petrol. Geol., Geol. Soc. Am., Appalachian Geol. Soc., Lic. Prof. Geol. VA (#203), PGC V. Chmn. Atlantic Area Comm.

SZEPE, Richard W. (2): Gen. Mgr. of Res. Eval., TX Eastern Gas Pipeline Co., Houston, TX (1986-), Mgr. (1984-86), Supr., Future Dev., (1983-84), Engr. (1982-83); Internal Rev. Svc., Petrol. Engr. (1978-82). Mem. Soc. Petrol. Engr., Offshore CONGR Comm., Alt. GRI (Gas Storage Steering Comm.), PGC Rocky Mtn. Area Comm.

THOMPSON, Wayne M. (5): Chief, Gas Supply Branch, Off. of Pipeline & Prod. Reg., Fed. Energy Reg. Comm., Washington, DC (1967-); Geol. Consultant, Oil & Gas, El Dorado, AR (1961-67); Robbins Petrol. Corp., Geol. Engr., Longview, TX (1959-61); Petrol. Inc., Geol., Shreveport, LA (1958-59); McAlester Fuel Co., Magnolia, AR (1954-58). PGC Observer - FERC.

TIPTON, Merlin J. (3): State Geol., Am. Assoc. of State Geol., Vermillion, SD. PGC Observer - AASG.

TITTERLE, Dan (1): Sr. Reservoir Engr., Energy Corp., San Antonio, TX (1988); Petrol. Assoc., Consultant, Woodlands, TX (1986-88); First Energy Corp., Western Div. Geol., Houston, TX (1985-86); Valero Prod. Co., Sr. Geol., San Antonio, TX (1980-85); Penzoil Co., Sr. Res. Geol., Houston, TX (1976-80); Eason Oil Co., Geol., Oklahoma City, OK (1974-76). Mem. El Paso Geol. Soc., So. TX Geol. Soc., Am. Assoc. Petrol. Geol. (Comm. Comp. App., Ind. Liaison, State Reg. Geol., DPA), Houston Geol. Soc., Soc. Petrol. Engr., Reg. Geol. TN, AR, PGC Gulf Coast Area Comm.

TONNSEN, John J. (5): Oil & Gas Atty., Consult., Billings, MT (1987-); General Hydrocarbons, Inc., V. Pres. Expl., Billings, MT (1981-87); The Montana Power Co., Sr. Expl., Billings, MT (1975-81); Shell Oil Co., Gen. Expl. Attorney, New York, Denver (1967-73); Pan Am. Petrol. Co., Expl. Field Geol., MT, ID, CO, UT (1960-62). Mem. Am. Assn. Petrol. Geol., MT Geol. Soc., MT, CO State Bar Assn., Fed. Energy Bar Assn., PGC Rocky Mtn. Area Comm.

TRAMEL, Lee R. (2): Mgr., Res., TN Gas Pipeline Grp., Houston, TX (1980-); Tenneco Oil Co., Res. Engr., Geol. Engr. Lafayette, LA, Houston, TX (1970-79); Coastal States Gas Prod. Co., Res. Engr., Corpus Christi, TX (1965-69); Bureau of Mines, Petrol. & Nat. Gas Engr., Amarillo, TX (1962-64); Fed. Power Comm., Pet. & Nat. Gas Engr., Washington, DC (1960-61); Lane Wells Co., Field Service Engr., Houma, LA (1958-59). Mem. Am. Assn. Petrol. Geol., Soc. Petrol. Engr., Soc. Prof. Well Log Anal., Cert. Geol., PGC Gulf Coast Area Comm.

VAN TYNE, Arthur M. (2): Geol. Consultant, Van Tyne Consulting, Wellsville, NY (1981-); NY State Geol. Surv., Sr. Geol.-in-Charge, State Oil & Gas Office, Wellsville, Alfred, NY (1958-81); Shell Oil Co., Geol., Baton Rouge, LA (1955-57), Geol. Training, Houston, TX (1954-55), Geol., Jackson, MS (1954), Field Geol., Denver, CO (1953-54); Syracuse Univ. Res. Inst., Refract. Seis. Crew, Intern, Geol. Div., Syracuse, NY (1951-53). Mem. Am. Assn. Petrol. Geol., Am. Petrol. Inst. (Subcomm. oil res., NY, PA, Comm. on Stat. of Drilling, 1965-), Buffalo Assn. Prof. Geol., Ind. Oil & Gas Assn. NY (Pres. 1985-88, Sec., Dir.), Int'l Oil Scouts Assn., Interstate Oil Compact

Comm. (Res. Comm.), NY State Geol. Assn., NY State Oil Prod. Assn. (Dir.), No. Appalachian Geol. Soc. (Past Pres.), The NY Acad. of Sci., PGC Atlantic Area Comm.

*VAUGHAN, William L. (7): V. Pres., Supply Plan. & Eval., TX Eastern Gas Pipeline Co., Houston, TX (1987-), Gen. Mgr. Res. Eval. Dept. (1973-87), TX Eastern Trans. Corp., Asst. Mgr. Res. & Del. (1972-73), Jr. Petrol. Engr., Engr. Gas Supply Dept. (1957-72). Mem. Am. Gas Assn. (Chmn., Underground Gas Storage Comm.), Soc. Petrol. Engr. (Nat. Gas Supply Project Adv.), Gas Res. Inst. (Storage Research Comm.), Nat. Gas Assn. of Houston, New Orleans, PGC Rocky Mtn. Area Comm.

WAINWRIGHT, Kenneth E. (5): Consulting Geol., Bakersfield, CA (1985-); ARCO Oil & Gas Co., Supr. Petro. Engr., Sr. Geol. Assoc., Bakersfield, CA (1979-85), Sr. Geol. (1977-79), Geol. (1970-77), Geol., Roswell, NM (1967-70), Geol., Denver, CO (1962-67). Mem. Am. Assn. Petrol. Geol., San Joaquin Geol. Soc., PGC V. Chmn. Pacific Area Comm.

WATERMAN, Douglas R. (9): Mgr. Dev. Geol., Western Reg. Expl. Dept., San Ramon, CA Chevron U.S.A. Inc., Asst. to Gen. Mgr. Western Reg. Expl. Dept.; Mgr. Dev. Geol., Western Reg. Prod. Dept., Standard Oil Co. of CA; Geol. Consultant/Adv., Foreign Oper. Staff, San Francisco, CA, Chevron U.S.A. Inc.; Dist. Supt. Sacramento-San Joaquin Dist, Dist. Supt., Coastal Dist., So. CA; Dist. Geol., Ventura Dist., Western Dist., So. CA; Area Geol., Santa Barbara Channel, CA, So. CA; Seismic Crew Rep., LA & Sacramento Basins & Salton Trough, CA, Cook Inlet, AK, So. CA; Dist. Geol., Salinas, So. San Joaquin Basins, So. CA; Geol., Subsurf. Geol., San Joaquin, Salinas, Santa Maria Basins, CA, So. CA; Geol., Oil Field Study & Second Recovery, San Joaquin Basin, CA, So. CA; Geol., Well Site Geol., Central, So. CA, So. CA. Mem. Am. Assn. Petrol. Geol., No. CA Geol. Soc., CA Reg. Geol. (#695), Soc. Petrol. Engr., PGC Pacific Area Comm.

WEAGANT, Frank E. (4): Retired, Dana Pt., CA (1989); Nahama & Weagant Energy Co., Chmn. Bd., Bakersfield, CA (1981-89), Consulting Geol., Pres. (1965-81); Franco Western Oil Co., Head Geol., Geol. (1955-65); Chevron U.S.A. Inc., Geol. (1951-55). Mem. Am. Assn. Petrol. Geol., PGC Pacific Area Comm.

* Pipelines representative.

** Gas distributors representative.

WIGAL, James M. (6): Dist. Expl. Mgr., Adobe Res. Corp., Pittsburgh, PA (1981-); Geol./Geophys./Expl. Mgr., The Peoples Nat. Gas Co. (1975-81); Dept. of Energy/Bureau of Mines, Geol., Morgantown, WV (1974-75). Mem. Am. Assn. Petrol. Geol., Soc. Econ. Paleon. & Min., Soc. Econ. Geol., Soc. Prof. Well Log Anal., PGC Chmn. Atlantic Area Comm.

WILSON, Garry D. (1): Dir., Anadarko Res. Engr. & Storage, var. underground storage, res. engr. pos., ENRON Corp., Houston, TX. (1973-). Mem. Soc. Petrol. Engr., Am. Gas Assn., PGC Mid-Continent Area Comm.

WOODBURY, H. O. (4): Geol., Denver, CO (1984-); Chevron U.S.A. Inc., Div. Geol. Rocky Mtn. Div., Denver, CO. (1981-84); Standard Oil Co. of CA, Indonesia (1979-81), New Orleans, LA (1972-81), Tripoli, Libya (1971-72), New Orleans, LA (1965-71); Chevron Research Corp., LaHabra, CA (1964), New Orleans, LA (1955-64), Casper, WY, Denver, CO (1946-55). Mem. Am. Assn. Petrol. Geol. (CPG), Rocky Mtn. Assn. Geol., PGC Chmn. Rocky Mtn. Area Comm.

WOODSON, James C. (3): V. Pres., Expl., Samedan Oil Corp., Ardmore, OK (1983-), Div. Gen. Mgr., Oklahoma City, OK (1978-83), Div. Geol., Oklahoma City, OK (1974-78). Mem. Am. Assn. Petrol. Geol., Am. Inst. Prof. Geol., OK City Geol. Soc., Ardmore Geol. Soc., PGC Mid-Continent Area Comm.

**YU, Peter D. (2): Gas Supply Forecasting Mgr., So. CA Gas Co., Los Angeles, CA (1986-), Sr. Gas Supply Analyst, (1983-86), Resident Reservoir Engr. (1982-83), Drilling Engr. (1980-82); Exxon U.S.A., Offshore Drilling Engr., New Orleans, LA (1978-80). PGC Chmn. Pacific Area Comm.



Mid-Continent Rift
Exploration interest has been focused on the Mid-Continent Rift Zone which traverses the North Central Area from northeastern Kansas and Nebraska to northern Minnesota and Wisconsin. The feature is defined primarily on the basis of geophysical data. It is postulated that considerable thicknesses of sedimentary rocks were deposited along this tectonic trend in elongate fault-block basins which may contain potential reservoir and source rocks. The faulting which is associated with the Rift Zone may have originated in Precambrian time and have continued to affect Paleozoic sedimentation as well.

Exposed Sediments
Concealed Sediments

Eastern Thrust Belt
Geophysical data and resulting exploratory activity have led to the interpretation of an Eastern Thrust Belt extending from Canada southward into Georgia and Alabama. In the western portion of this belt, sedimentary rocks are exposed at the surface. In the eastern portion, sedimentary rocks are believed to exist beneath metamorphic rocks. Preliminary estimates of natural gas resources for the Eastern Thrust Belt are included in the estimates reported for the Atlantic Area.

Lower Mobile Bay Norphlet Play
Significant natural gas has been discovered in Lower Mobile Bay and the immediately adjacent federal waters in an eolian facies of the Norphlet Formation. Producing depths exceed 20,000 feet. Fields found to date are estimated to range in size from 200 Bcf to in excess of 1 Tcf. Lateral extent of the play is not completely known, but estimates of the resource potential have been included in the estimates for provinces P-300 and P-600.

Exposed Sediments
Concealed Sediments

Plate 1
POTENTIAL GAS COMMITTEE
NATURAL GAS MAP OF THE UNITED STATES
December 31, 1988

- AREAS OF GAS PRODUCTION INCLUDING GAS ASSOCIATED WITH OIL
- AREAS IN WHICH SEDIMENTARY ROCKS ARE EXPOSED AT THE SURFACE OR ARE PRESENT AT DEPTH AND COVERED AT THE SURFACE BY EXTRUSIVE IGNEOUS ROCKS
- AREAS IN WHICH INTRUSIVE IGNEOUS ROCKS OR METAMORPHIC ROCKS ARE EXPOSED AT THE SURFACE
- LIMITS OF SEDIMENTARY BASINS AS RECOGNIZED BY THE POTENTIAL GAS COMMITTEE, DASHED WHERE INFERRED
- CONTOUR LINE INDICATING THICKNESS OF SEDIMENTS

Western Thrust Belt
The Western Thrust Belt, especially the central portion which is located along the Wyoming-Idaho border, has become a major target for exploration. Significant gas fields have been discovered in southwestern Wyoming and northern Utah. While the eastern boundary of this belt is fairly well defined by the limits of thrust faults, the western boundary is much more nebulous. Some interpretations extend the Western Thrust Belt southeastward from southern Nevada through Arizona, southeastern New Mexico, westernmost Texas and into Mexico. At the present time, the only areas within the Thrust Belt in which estimates of potential resources of natural gas have been made are the northern, central and southern portions indicated on the map. Because of lack of positive confirmation of the extension of the Thrust Belt south of Utah and the lack of data on potential source rocks, reservoir rocks and trapping mechanisms, no estimate of any potential resource of natural gas has been made for this area.

Exposed Sediments
Concealed Sediments

This map prepared by Terra Graphics in accordance with Potential Gas Committee report, Potential Supply of Natural Gas in the United States (as of December 31, 1988). Copies available from Potential Gas Agency, Colorado School of Mines, Golden, Colorado 80401. Phone: (303) 279-4120.